DOCUMENT RESUME

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IDENTIFIERS	*Aircraft Environmental Systems; Military Curriculum Project

ABSTRACT

This publication contains a teaching guide and student instructional materials for conducting a high school or adult vocational education course to train persons to perform duties as an aircraft environmental systems mechanic. Course content has been adapted from a military course. The instructional design for this course is self-paced and/or small group-paced. Instructor materials contained in the course guide include lesson plans detailing training equipment needed, training methods, multiple instructor requirements, and instructional guidance. The student material includes a workbook and programmed texts with review exercises. A bibliography and glossary of terms are provided to aid both teacher and students. The course includes information on organizational and field maintenance of aircraft pressurization, air conditioning, and air starter systems, and life raft inflation equipment. The course is composed of four parts (see note). Block I (contained in this document) is composed of 24 lessons requiring 115 hours of instruction. Topics covered include safety; aircraft familiarization; physics; electron theory; magnetism; DC generation and basic circuit symbols and terms; wiring diagram fundamentals; control and protective devices; multimeter; Kirchoff's current and voltage laws; Ohm's law; circuits; alternating current; capacitance; inductance; AC and DC motors and control circuits; solid state devices; magnetic amplifiers; and trainer aircraft air conditioning system. (KC)

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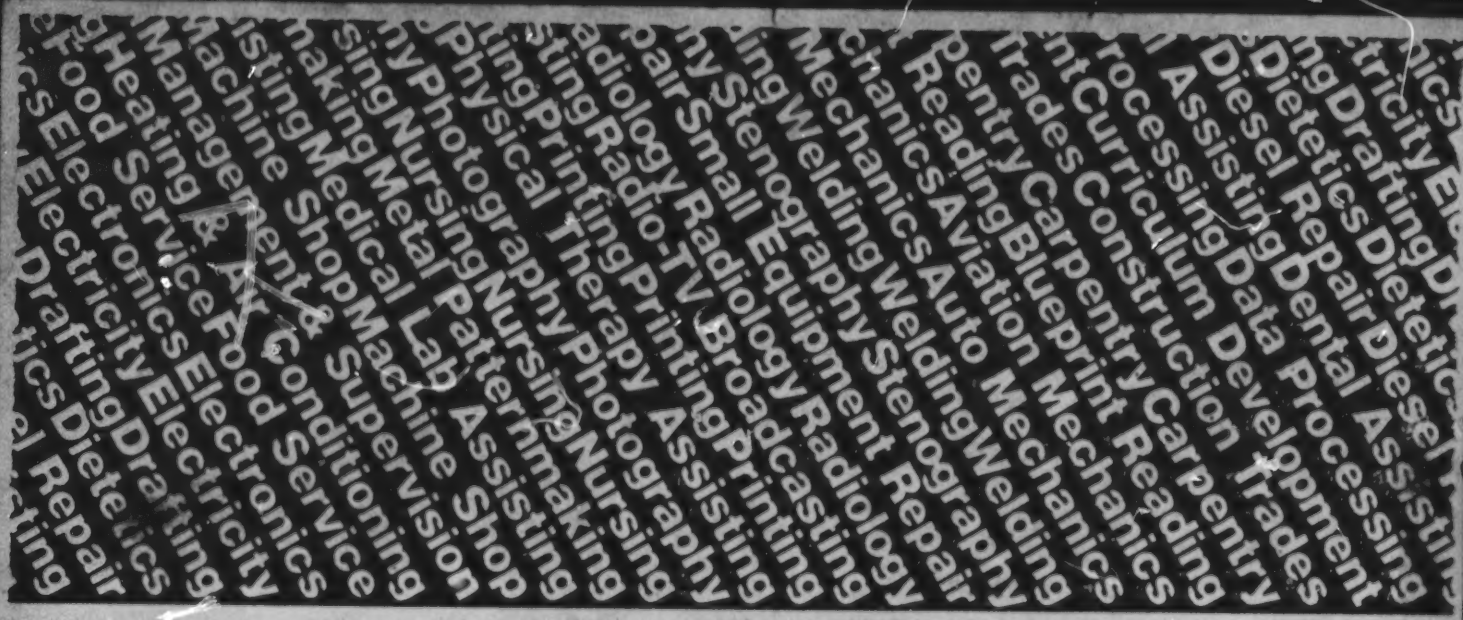

ED212795

Military Curriculum Materials for Vocational and Technical Education

AIRCRAFT ENVIRONMENTAL SYSTEM MECHANIC, 2-9
BLOCK I - FUNDAMENTALS

U.S. DEPARTMENT OF EDUCATION
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THE NATIONAL CENTER FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY
1960 KENNY ROAD · COLUMBUS, OHIO 43210

CE031189

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

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Military Curriculum Materials
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The Ohio State University
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THE NATIONAL CENTER FOR RESEARCH IN VOCATIONAL EDUCATION

Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

AIRCRAFT ENVIRONMENTAL SYSTEM MECHANIC
3ABR42331

Classroom Course 2-9

Developed by:
United States Air Force

Occupational Area:
Aviation

Development and Review Dates:
October 17, 1978

Target Audiences:
Grades 11 - adult

Print Pages:
3122

Availability:
ERIC
National Center Clearinghouse

Contents:	Type of Materials: Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Instructional Design: Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Type of Instruction: Group Instruction:	Individualized:
* Block I -												
Fundamentals	•	•	•		•		•		•		•	•
Block II -												
Air Conditioning Systems	•	•	•		•	X	•		•		•	•
Block III -												
Aircraft Environmental Systems Units	•	•	•		•	X	•		•	X	•	•
Block IV -												
Utility Systems and Flight Line Maintenance	•	•		•	•	X	•		•	X	•	•

X Materials are recommended but not provided.

2.

C3ABR42331

Course Description

The instructional design for this course is self-paced and/or small group paced. This course trains personnel to perform duties as an Aircraft Environmental Systems Mechanic. It includes organizational and field maintenance of aircraft pressurization, air conditioning and air starter systems, and life raft inflation equipment.

Block I - Fundamentals contains 24 lessons requiring 115 hours of instruction. These are: safety; aircraft familiarization; physics; electron theory; magnetism; DC generation and basic circuit symbols and terms; wiring diagram fundamentals; control and protective devices; multimeter; Kirchoff's current law; Kirchoff's voltage law; Ohm's law; series circuits; parallel circuits; series-parallel circuits; switching circuits; DC motors and control circuit; temperature control circuits; alternating current; capacitance; inductance; AC motors and control circuits; solid state devices; magnetic amplifiers; and trainer aircraft air conditioning system.

Block II - Air Conditioning Systems consists of 8 lessons convering 124 hours of instruction. These are: fighter cabin air conditioning system; rain removal system; equipment air conditioning system; temperature control system tester; bomber air conditioning system; decade resistor functions and windshield amplifier bench check; cargo bleed air and anti-icing system; and cargo air conditioning system.

Block III - Aircraft Environmental Systems Units contains 13 lessons covering 102 hours of instruction. These are the following: tools, hardware, safetying devices, and wire repair; maintenance of moisture separators; maintenance of bleed air distribution ducting; air turbine motor maintenance; turbine refrigeration devices; advanced fighter/bomber air source control system; advanced fighter/bomber air conditioning system; advanced fighter/bomber windshield clearing system; maintenance of air control units; anti-G suit system; canopy seal system; pressurization systems; and cabin pressure leakage check.

Block IV - Utility Systems and Flight Line Maintenance consists of 9 lessons requiring 114.5 hours of instruction. These lessons are entitled: gaseous O_2 systems; liquid O_2 systems; liquid refrigeration systems and components; inspection maintenance of O_2 systems (liquid); cryotainer systems maintenance; liferaft inflation equipment, fire extinguisher system maintenance; flight line maintenance - inspections; and flight line maintenance; removal and replacement of system components.

This course contains both teacher and student materials. Printed instructor materials include plans of instruction detailing training equipment needed, training methods, multiple instructor requirements and instructional guidance. The student material includes workbook, and programmed texts with review exercises. A bibliography and glossary of terms have been provided to aid both the instructor and the student. In Blocks I and III, lessons on Orientation, Security, Progression in Career Field, Maintenance Management, and the Technical Order Publications Systems have been deleted because of military specific materials.

TABLE OF CONTENTS

Block		Page
I.	Fundamentals	225
II.	Air Conditioning Systems	1253
III.	Aircraft Environmental Systems Units	1850
IV.	Utility Systems and Flight Line Maintnenance	2628

NOTE: Lessons 1-3 of Block I and Lessons 1-2 of Block III have been deleted because of military specific materials.

COURSE CHART

NUMBER	POI CODE	DATE
C3ABR42331 000	ANZ	29 September 1978

COURSE TITLE
Aircraft Environmental Systems Mechanic

SUPERSEDES COURSE CHART	CENTER/DEPARTMENT/GROUP
3ABR42331, 20 October 1976	Chanute/3370 TCHTG

APPLICABLE TRAINING STANDARD
STS 423X1, September 1978

OPR AND APPROVAL DATE	COURSE SECURITY CLASSIFICATION
Chanute/TTGXS, 13 October 1978	UNCLASSIFIED

INSTRUCTIONAL DESIGN	LOCATION OF TRAINING	TABLE ATTACHMENTS
Self-Paced	Chanute AFB IL 61968	II

COURSE LENGTH I 70 ACADEMIC DAYS * WARTIME COURSE LENGTH 70 ACADEMIC DAYS

	HOURS
Technical Training	508
Military Training	52
TOTAL	560

*Course conducted 6 days per week

REMARKS

Effective Date: 17 October 1978 with Class 781017

Previous classes will be continued with Course Chart 3ABR42331, 20 October 1976

This course is conducted on an 8-hour training day.

TABLE I - MAJOR ITEMS OF EQUIPMENT

Training Equipment: Gaseous Oxygen Systems Trainers, Liquid Oxygen System Trainers, Air Conditioning System Trainers, Temperature Control System Trainers, Environmental Systems Trainer, Aircraft Hardware Trainers, Fire Extinguishing Trainer, Air Turbine Motor, Bridge Circuit Trainers, AC Valve Control System Trainers, DC Reversible Motor Trainer, Electrical Pneumatic Components, Test Stand Trainers, Rain Removal System Trainers, Electrical Fundamentals Trainers, Handtool Trainers, Wire Maintenance Trainer, Anti-G Valve Trainer, Torque Wrench and Safety Wire Trainer, Carbon Dioxide Recharging Unit, Scales, Hot Purge Units Vacuum Pump Aircraft, Cryotainer Storage Tanks.

Test Equipment: Multimeters, Flow Meters, Cockpit Pressure Leak Testers, Temperature Control System Testers, Anti-G Suit Valve Tester, Oxygen Regulator Testers, Adapter Cabin Temperature Tester, Liquid Oxygen Converter Tester, Liquid Oxygen Capacitance System Tester, Sonic Leak Detector, Ignitor Circuit Tester, Oxygen System Master Test Gage, Decade Box, Vacuum Micron Gage.

5

COURSE CHART C3ABR42331 TABLE II TRAINING CONTENT

Course Material - UNCLASSIFIED 153 Hours
BLOCK I - Fundamentals

Orientation (6.5 hrs); Security (2 hrs); Progression and Duties of the Aircraft Environmental Systems Career Field (2 hrs); Safety (3 hrs); Aircraft Familiarization (3 hrs); Physics of Solids, Liquids and Gases (1.5 hrs); Electron Theory (4.5 hrs); Magnetism (2.5 hrs); DC Generation and Basic Circuit Symbols and Terms (3 hrs); Wiring Diagrams (3.5 hrs); Control and Protective Devices (2 hrs); Multimeter (12.5 hrs); Measurement and Critique (1.5 hrs); Kirchoff's Current Law (2.5 hrs); Kirchoff's Voltage Law (2.5 hrs); Ohm's Law (2.5 hrs); Series Circuits (3 hrs); Parallel Circuits (3 hrs); Series-Parallel Circuits (15 hrs); Switching Circuits (3 hrs); DC Motors and Control Circuits (8.5 hrs); Temperature Control Circuits (10 hrs); Alternating Current (1 hr); Capacitance (0.5 hr); Inductance (0.5 hr); AC Motors and Control Circuits (10 hrs); Solid State Devices (1.5 hrs); Magnetic Amplifiers (4 hrs); Trainer Aircraft Air Conditioning System (12.5 hrs); Measurement and Critique (1.5 hrs); Military Training (24 hrs).

(Equipment Hazards and Personnel Safety Integrated With Above Subjects)

Course Material - UNCLASSIFIED 135 Hours
BLOCK II - Air Conditioning Systems

Fighter Cabin Air Conditioning Systems (24 hrs); Rain Removal Systems (13 hrs); Equipment Air Conditioning System (16 hrs); Temperature Control System Tester (7 hrs); Measurement and Critique (1.5 hrs); Bomber Air Conditioning System (24 hrs); Decade Resistor Functions and Windshield Amplifier Bench Check (2 hrs); Cargo Bleed Air and Anti-Icing System (18 hrs); Cargo Air Conditioning System (22 hrs); Measurement and Critique (1.5 hrs); MT (6 hrs).

(Equipment Hazards and Personnel Safety Integrated With Above Subjects)

COURSE CHART C3ABR42331 TABLE II TRAINING CONTENT

Course Material - UNCLASSIFIED 141 Hours
BLOCK III - Environmental Systems Units

Maintenance Management (15 hrs); Technical Order Publication Systems (12 hrs); Tools, Hardware, Safetying Devices and Wire Repair (18 hrs); Maintenance of Moisture Separators (3 hrs); Maintenance of Bleed Air Distribution Ducting (3 hrs); Turbine Refrigeration Devices (3 hrs); Advanced Fighter-Bomber Air Source Control System (11 hrs); Advanced Fighter-Bomber Air Conditioning System (15 hrs); Measurement and Critique (2 hrs); Advanced Fighter-Bomber Windshield Clearing System (10 hrs); Maintenance of Air Control Units (14 hrs); Anti-G Suit System (2 hrs); Canopy Seal System (4 hrs); Pressurization Systems (12 hrs); Air Turbine Motor Maintenance (3 hrs); Cabin Pressure Leakage Check (4 hrs); Measurement and Critique (2 hrs); MT (8 hrs).

(Equipment Hazards and Personnel Safety Integrated With Above Subjects)

Course Material - UNCLASSIFIED 131 Hours
BLOCK IV - Utility Systems and Flight-Line Maintenance

Gaseous Oxygen Systems (4 hrs); Liquid Oxygen Systems (4 hrs); Inspection and Maintenance of Liquid Oxygen Systems (16 hrs); Cryotainer Systems Maintenance (24 hrs); Life Raft Inflation Equipment (5.5 hrs); Fire Extinguisher System Maintenance (8 hrs); Liquid Refrigeration Systems and Components (13.5 hrs); Measurement and Critique (1.5 hrs); Flight-Line Maintenance, Inspection (16 hrs); Flight-Line Maintenance, Removal and Replacement of System Components (24 hrs); Course Critique and Graduation (0.5 hr); MT (14 hrs).

(Equipment Hazards and Personnel Safety Integrated With Above Subjects)

POI 3AERL2331
(PDS Code ANZ)

PLAN OF INSTRUCTION
(Technical Training)

AIRCRAFT ENVIRONMENTAL SYSTEMS MECHANIC

CHANUTE TECHNICAL TRAINING CENTER (ATC)

17 October 1978 - Effective 17 October 1978 with class 781017

DEPARTMENT OF THE AIR FORCE
Deputate for Technical Training (ATC)
Chanute Air Force Base, Illinois 61868

PLAN OF INSTRUCTION C3AER42331
(PDS Code ANZ)

FOREWORD

1. PURPOSE. This publication is the plan of instruction (POI) when the pages shown on page A are bound into a single document. The POI prescribes the qualitative requirements for Course Number C3AER42331, Aircraft Environmental Systems Mechanic, in terms of criterion objectives and teaching steps presented by units of instruction and shows duration, correlation with training standard, and support materials and guidance. When separated into units of instruction, it becomes Part I of the lesson plan. This POI was developed under the provisions of AFR 50-8, Instructional Systems Development, and ATCR 52-7, Plans of Instruction and Lesson Plans.

2. COURSE DESIGN/DESCRIPTION. The instructional design for this course is self-paced and/or small group paced. This course trains personnel to perform duties prescribed in AFM 39-1 for Aircraft Environmental Systems Mechanic, AFSC 42331. It includes organizational and field maintenance of aircraft pressurization, air conditioning (heating, cooling, humidity control, etc.), engine bleed air, oxygen, anti-icing, defogging, fire extinguishing, air turbine, and air starter systems, and life raft inflation equipment. In addition, related training is provided on driver education, supplemental military training, troop information program, commander's calls/briefings, etc. The student will not necessarily complete training as programmed. Sequence changes are required to expedite student progress. Multiple Instructor Requirements are based on Manpower Course Evaluation Data Sheets dated 11 August 1978.

3. TRAINING EQUIPMENT. The number shown in parentheses after equipment listed as Training Equipment under SUPPORT MATERIALS AND GUIDANCE is the planned number of students assigned to each equipment unit.

4. REFERENCES. This plan of instruction is based on Specialty Training Standard 423X1, September 1978 and Course Chart C3AER42331, 29 September 1978.

FOR THE COMMANDER

John L. O'Donnell Jr.

JOHN L. O'DONNELL, JR., Colonel, USAF
Commander, 3370 Technical Training Group

Supersedes Plan of Instruction 3AER42331, 22 December 1976
OPR: 3370 TCHTG
DISTRIBUTION: Listed on Page A

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
4. Safety a. Select the safe work habits and procedures consistent with shop and flight line safety with a minimum of 80% accuracy. STS: 3a Meas: W b. Select the two required protective devices used for protection from high intensity sound hazards. STS: 3b Meas: W c. Select general housekeeping procedures which are consistent with shop, flight line and fire protection with a minimum of 80% accuracy. STS: 3c Meas: W d. Select the marking that is applicable to radioactive parts and materials. STS: 3d Meas: W e. Select the protective measures used against radiation hazards with a minimum of 80% accuracy. STS: 3e Meas: W f. Select the protective measure used against high frequency transmission equipment. STS: 3f Meas: W g. Select the safety precautions that will be observed while working around danger areas with a minimum of 80% accuracy. STS: 3g Meas: W NOTE: Numbers 1-3 of Block I have omitted because of military specific materials.	3

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
3AEB42331	17 October 1978	7

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEB42331-PT-104 (3AEB42331-PT-102) Safety

Training Methods
Self-Instruction (3 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
5. Aircraft Familiarization a. Select elements used to make up the aircraft designation system with a minimum of 80% accuracy. STS: 9a, 9b Meas: W b. Select the terms and elements of the aircraft station numbering system with a minimum of 80% accuracy. STS: 9c Meas: W c. Select major aircraft systems when given their purpose with a minimum of 80% accuracy. STS: 9d Meas: W	3

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
3ABR42331	17 October 1978	9

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3ABR42331-PT-105, Aircraft Familiarization

Training Methods
Self-Instruction (3 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
6. Physics a. Select the result that would occur from a change in pressure and/or temperature on gases with a minimum of 80% accuracy. STS: 11c Meas: W b. Select the result that would occur from a change in atmospheric conditions on pressure, temperature, and humidity control with a minimum of 80% accuracy. STS: 11d Meas: W	1.5

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
3ABR42331	17 October 1978	11

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AHR42331-PT-106 (3AHR42331-PT-111), Physics of Solids, Liquids and Gases

Training Methods
Self-Instruction (1.5 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
7. Electron Theory	4.5
a. Relate electrical characteristics of materials to the flow of electrical current with a minimum of 80% accuracy. STS: 11a, 12 Meas: W	
b. Select the result that would occur from a change in temperature on metals with a minimum of 80% accuracy. STS: 11b, 12 Meas: W	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
3AEB42331	17 October 1978	13

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AHR42331-PT-107, Electron Theory

Training Methods
Self-Instruction (4.5 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER I	BLOCK TITLE Fundamentals

1 COURSE CONTENT	2 TIME
8. Magnetism a. Given a list of materials, select those that can be used to make temporary and permanent magnets with 80% accuracy. STS: 12 Meas: W b. Select the effects of lines of force when given the laws of magnetism with 80% accuracy. STS: 12 Meas: W	2.5

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
3AHR42331	17 October 1978	15

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3ABR42331-PT-108 (3ABR42331-PT-105A), Magnetism

Training Methods
Self-Instruction (2.5 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER I	BLOCK TITLE Fundamentals

1 COURSE CONTENT	2 TIME
9. DC Generation and Basic Circuit Symbols and Terms	3
a. Select basic facts, terms and laws used in the generation of an electromagnetic field with a minimum of 80% accuracy. STS: 12 Meas: W	
b. Select the basic symbols and terms used in electrical circuits with a minimum of 80% accuracy. STS: 12 Meas: W	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
3ABB42331	17 October 1978	17

ATC FORM OCT 78 133 PREVIOUS EDITION IS OBSOLETE

COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-109 (3AER42331-PT-105B), DC Generation and Basic Circuit Symbols and Terms

Training Methods
Self-Instruction (3 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

COURSE CONTENT	% TIME
10. Wiring Diagram Fundamentals a. Select five (5) of the six (6) elements that make up the wire numbering system. STS: 12, 13b, 13c Meas: W b. Select common symbols of wiring diagrams, with a minimum of 80% accuracy. STS: 12, 13b, 13c Meas: W	3.5

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3ABR42331-PT-110 (3ABR42331-PT-117), Wiring Diagrams Fundamentals

Training Equipment
Trainer P/N 18 71 4112 Electrical Components (1)
Trainer P/N 18 71 4113 Bridge Circuits Components (1)
Trainer P/N 18 71 4114 Electrical Components (1)

Training Methods
Self-Instruction (3.5 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTION	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
11. Control and Protective Devices a. Select the control and protective devices used in electrical circuits with a minimum of 80% accuracy. STS: 12 Meas:W b. Select the control and protective device symbols and terms used in electrical circuits with a minimum of 80% accuracy. STS: 12 Meas: W	2

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3ABR42331-PT-111 (3ABR42331-PT-105C), Control and Protective Devices

Training Equipment
Trainer P/N 18 71 4112 Electrical Components (1)
Trainer P/N 18 71 4113 Bridge Circuit Components (1)
Trainer P/N 18 71 4114 Electrical Components (1)

Training Methods
Self-Instruction (2 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER I	BLOCK TITLE Fundamentals

ℓ	COURSE CONTENT	Σ TIME
	12. Multimeter	12.5
	a. Associate the controls of a multimeter to their function and interpret meter scale indications with a minimum of 80% accuracy. STS: 14a(1) Meas: W	(9.5)
	* b. Using a multimeter, voltage and resistive console, measure and record electrical and resistive values with ± 10% of the actual values. STS: 14a(1) Meas: PC	(3.0)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEB42331-PT-112 (3AEB42331-PT-108), Use of Test Equipment (PSM-37 Multimeter)
3AEB42331-WB-112 (3AEB42331-WB-108), AN/PSM-37 Multimeter Performance

Training Equipment
Multimeter (PSM-37) (1)
Trainer P/N 18 70 4104, Multimeter Voltage/Resistance Console (1)

Training Methods
Self-Instruction (9.5 hrs)
Performance (3 hrs)

Multiple Instructor Requirements
Supervision, Equipment (3) 12b

Instructional Guidance
The classroom and/or lab instructor will instruct/supervise the student class study and/or lab period, continually administer, evaluate, and critique appraisals, performance exercises, and performance test as each student progresses, record attendance, insure student has correct module material and equipment, record students progress, maintain each student ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. Safety in the labs includes working with or around electrical/mechanical devices. This includes safe use of electrical test equipment, working with 28VDC 5-10 amp circuits and/or working with 115VAC 400 cycle single phase power. The instructor will provide individual assistance to each student as needed during class/lab periods. Each student must satisfactorily complete the individual appraisal and/or performance exercise and/or performance tests to satisfy the objective(s). The instructor will pick up all reusable training literature from the student as is feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

13. Measurement and Critique 1.5

a. Measurement Test

b. Test Critique

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NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER I	BLOCK TITLE Fundamentals

1 COURSE CONTENT	2 TIME
14. Kirchhoff's Current Law a. Use Kirchhoff's current law to solve for unknown values in basic electrical circuits. A minimum of eight (8) out of ten (10) unknown values must be correct. STS: 12, 13b Meas: W	2.5

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3ABR42331-PT-114 (3ABR42331-PT-111), Kirchhoff's Current Law

Training Methods
Self-Instruction (2.5 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide, for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
15. Kirchhoff's Voltage Law a. Use Kirchhoff's voltage law to solve for unknown values in basic electrical circuits. A minimum of eight (8) out of ten (10) unknown values must be correct. STS: 12, 13b Meas: W	2.5

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-115 (3AER42331-PT-111A) Kirchhoff's Voltage Law

Training Methods
Self-Instruction (2.5 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

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NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER I	BLOCK TITLE Fundamentals

ITEM	COURSE CONTENT	TIME
1	16. Ohm's Law a. Use Ohm's law and power formulas to solve for unknown values in basic electrical circuits. A minimum of eight (8) out of ten (10) circuits must be correct. STS: 12, 13b Meas: W	2.5

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEB42331-PT-116 (3AEB42331-PT-111B), Ohm's Law

Training Methods
Self-Instruction (2.5 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
17. Series Circuits	3
a. Using Kirchhoff's current and voltage laws, and Ohm's law, solve for unknown values in series circuits. A minimum of eight (8) out of ten (10) circuits must be correct. STS: 12, 13b Meas: W	
* b. Using a DC fundamental trainer, construct a series circuit and measure electrical values with one instructor assist allowed for each task area. STS: 3a, 12, 13b Meas: PC	

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-117 (3AER42331-PT-114), Series Circuit
3AER42331-WB-117 (3AER42331-WB-111), Series Circuit Performance

Training Equipment
Multimeter (PSM-37) (1)
Trainer P/N 18 52 1685, DC Electrical Fundamentals (1)

Training Methods
Self-Instruction (1 hr)
Performance (2 hrs)

Multiple Instructor Requirements
Supervision, Equipment (5) 17b

Instructional Guidance
The classroom and/or lab instructor will supervise the student class study and/or lab period, continually administer, evaluate, and critique appraisals, performance exercises, and performance test as each student progresses, record attendance, insure student has correct module materials and equipment, record students progress, maintain each student ATC 156 record, monitor student movement to complete this module between two stations, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. Safety in the labs includes working with or around electrical/mechanical devices. This includes safe use of electrical test equipment, working with and/or construction of 28VDC 5-10 amp circuits and/or working with 115VAC 400 cycle single and/or three phase power. The instructor will provide individual assistance to each student as needed during class/lab periods. Each student must satisfactorily complete the individual appraisals, and/or performance exercise and/or performance tests to satisfy the objectives. The instructor will pick-up all reusable training literature from the student as is feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
18. Parallel Circuits a. Using Kirchhoff's current and voltage laws, and Ohm's law, solve for unknown values in parallel circuits. A minimum of eight (8) out of ten (10) circuits must be correct. STS: 12, 13b Meas: W * b. Using a DC fundamental trainer, construct a parallel circuit and measure electrical values with one instructor assist allowed for each task area. STS: 3a, 12, 13b Meas: PC	3

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEBR42331-PT-118 (3AEBR42331-PT-111D), Parallel Circuits
3AEBR42331-WB-118 (3AEBR42331-WB-111A), Parallel Circuits Performance

Training Equipment
Multimeter (PSM-37) (1)
Trainer P/N 18 52 1685, DC Electrical Fundamentals (1)

Training Methods
Self-Instruction (1 hr)
Performance (2 hrs)

Multiple Instructor Requirements
Supervision, Equipment (5) 18b

Instructional Guidance
The classroom and/or lab instructor will supervise the student class study and/or lab period, continually administer, evaluate, and critique appraisals, performance exercises, and performance test as each student progresses, record attendance, insure student has correct module materials and equipment, record students progress, maintain each student ATC 156 record, monitor student movement to complete this module between two stations, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. Safety in the labs includes working with or around electrical/mechanical devices. This includes safe use of electrical test equipment, working with and/or construction of 28VDC 5-10 amp circuits and/or working with 115VAC 400 cycle single and/or three phase power. The instructor will provide individual assistance to each student as needed during class/lab periods. Each student must satisfactorily complete the individual appraisals, and/or performance exercise and/or performance tests to satisfy the objectives. The instructor will pick-up all reusable training literature from the student as is feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

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NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

ℓ	COURSE CONTENT	± TIME
	19. Series-Parallel Circuits	15
	a. Using Kirchhoff's current and voltage laws, Ohm's law, and power formula, solve for unknown values in series-parallel circuits. A minimum of eight (8) out of ten (10) circuits must be correct. STS: 12, 13b Meas: W	(10)
	b. Using schematic diagrams of electrical circuits, malfunction indications, and meter readings, select the type of trouble for a minimum of eight (8) out of ten (10) indications. STS: 12, 13b Meas: W	(3)
	* c. Using a DC fundamental trainer, construct a series-parallel circuit and measure electrical values with one instructor assist allowed for each task area. STS: 3a, 12, 13b Meas: PC	(2)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-119 (3AER42331-PT-111E), Series-Parallel Circuits
3AER42331-WB-119 (3AER42331-WB-111B), Series-Parallel Circuits Performance

Training Equipment
Multimeter (PSM-37)
Trainer P/N 18 52 1685, DC Electrical Fundamentals (1)

Training Methods
Self-Instruction (13 hrs)
Performance (2 hrs)

Multiple Instructor Requirements
Supervision, Equipment (5) 19c

Instructional Guidance
The classroom and/or lab instructor will supervise the student class study and/or lab period, continually administer, evaluate, and critique appraisals, performance exercises, and performance test as each student progresses, record attendance, insure student has correct module materials and equipment, record students progress, maintain each student ATC 156 record, monitor student movement to complete this module between two stations, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. Safety in the labs includes working with or around electrical/mechanical devices. This includes safe use of electrical test equipment, working with and/or construction of 28VDC 5-10 amp circuits and/or working with 115VAC 400 cycle single and/or three phase power. The instructor will provide individual assistance to each student as needed during class/lab periods. Each student must satisfactorily complete the individual appraisals, and/or performance exercise and/or performance tests to satisfy the objectives. The instructor will pick-up all reusable training literature from the student as is feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

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NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
20. Switching Circuits	3
a. Select components of relay switching circuit, when given their purpose, with a minimum of 80% accuracy. STS: 12, 13b Meas: W	
* b. Using a DC fundamental trainer, construct a relay switching circuit and measure electrical values with one instructor assist allowed for each task area. STS: 3a, 12, 13b Meas: PC	

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEB42331-PT-120 (3AEB42331-PT-114B), Introduction to Relays
3AEB42331-WB-120 (3AEB42331-WB-111C), Relay Switching Circuit Performance

Training Equipment
Multimeter (PSM-37) (1)
Trainer P/N 18 52 1685, DC Electrical Fundamentals (1)

Training Methods
Self-Instruction (1 hr)
Performance (2 hrs)

Multiple Instructor Requirements
Supervision, Equipment (5), 20b

Instructional Guidance
The classroom and/or lab instructor will supervise the student class study and/or lab period, continually administer, evaluate, and critique appraisals, performance exercises, and performance test as each student progresses, record attendance, insure student has correct module materials and equipment, record students progress, maintain each student ATC 156 record, monitor student movement to complete this module between two stations, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. Safety in the labs includes working with or around electrical/mechanical devices. This includes safe use of electrical test equipment, working with and/or construction of 28VDC 5-10 amp circuits and/or working with 115VAC 400 cycle single and/or three phase power. The instructor will provide individual assistance to each student as needed during class/lab periods. Each student must satisfactorily complete the individual appraisals, and/or performance exercise and/or performance tests to satisfy the objectives. The instructor will pick-up all reusable training literature from the student as is feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

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NAME OF INSTRUCTOR

COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic

BLOCK NUMBER: I

BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
21. DC Motors and Control Circuit	8.5
a. Select components of DC motors when given their purpose with a minimum of 80% accuracy. STS: 12 Meas: W	(1.5)
b. Using an electrical diagram, identify a minimum of eight (8) out of ten (10) circuit malfunctions, when given the cause and circuit condition. STS: 12, 13b, 13c Meas: PC	(3)
* c. Using a DC motor control circuit, electrical diagrams, and multimeter, locate and record a minimum of four (4) causes for five (5) malfunctions. STS: 12, 13b, 13c, 16c Meas: PC	(4)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-121 (3AER42331-PT-113) DC Motors
3AER42331-WB-121 (3AER42331-WB-114) DC Motors and Control Circuits Wiring Diagram
3AER42331-WB-121A (3AER42331-WB-114A) DC Motors and Control Circuits Trouble-shooting

Training Equipment
Multimeter (PSM-37) (1)
Trainer P/N 18 50 1387 DC Reversible Motor System (1)
Trainer P/N 18 50 1318 Actuator Valve Assembly Display (1)

Training Methods
Self-Instruction (1.5 hrs)
Performance (7 hrs)

Multiple Instructor Requirements
Supervision, Equipment (3) 21b
Supervision, Equipment (5) 21c

Instructional Guidance
The classroom and/or lab instructor will supervise the student class study and/or lab period, continually administer, evaluate, and critique appraisals, performance exercises, and performance test as each student progresses, record attendance, insure student has correct module materials and equipment, record students progress, maintain each student ATC 156 record, monitor student movement to complete this module between three stations, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. Safety in the labs includes working with or around electrical/mechanical devices. This includes safe use of electrical test equipment, working with and/or construction of 28VDC 5-10 amp circuits and/or working with 115VAC 400 cycle single and/or three phase power. The instructor will provide individual assistance to each student as needed during class/lab periods. Each student must satisfactorily complete the individual appraisals, and/or performance exercise and/or performance tests to satisfy the objectives. The instructor will pick-up all reusable training literature from the student as is feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teching Guide for detailed instructions on this module.

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NAME OF INSTRUCTION	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
22. Temperature Control Circuits	10
a. Using Kirchhoff's current, voltage and Ohm's laws, solve for unknowns in temperature controlling bridge circuits. A minimum of eight (8) out of ten (10) unknowns must be correct. STS: 13a(1) Meas: W	(3)
b. Using an electrical diagram, identify a minimum of eight (8) out of ten (10) circuit malfunctions, when given the cause and circuit condition. STS: 13a(1), 13b, 13c Meas: PC	(3)
* c. Using a temperature control circuit, electrical diagrams, and multimeter, locate and record a minimum of four (4) causes for five (5) malfunctions. STS: 13b, 13c, 16c Meas: PC	(4)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEBR42331-PT-122 (3AEBR42331-PT-114), Temperature Controlling Bridge Circuits
3AEBR42331-WB-122 (3AEBR42331-WB-115), Temperature Control Circuits Wiring Diagram
3AEBR42331-WB-122A (3AEBR42331-WB-115A), Temperature Control Circuits Trouble-shooting

Training Equipment
Multimeter (PSM-37) (1)
Trainer P/N 18 63 3072 Bridge Circuit (1)

Training Methods
Self-Instruction (3 hrs)
Performance (7 hrs)

Multiple Instructor Requirements
Supervision, Equipment (3) 22b
Supervision, Equipment (5) 22c

Instructional Guidance
The classroom and/or lab instructor will supervise the student class study and/or lab period, continually administer, evaluate, and critique appraisals, performance exercises, and performance test as each student progresses, record attendance, insure student has correct module materials and equipment, record students progress, maintain each student ATC 156 record, monitor student movement to complete this module between three stations, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. Safety in the labs includes working with or around electrical/mechanical devices. This includes safe use of electrical test equipment, working with and/or construction of 28VDC 5-10 amp circuits and/or working with 115VAC 400 cycle single and/or three phase power. The instructor will provide individual assistance to each student as needed during class/lab periods. Each student must satisfactorily complete the individual appraisals, and/or performance exercise and/or performance tests to satisfy the objectives. The instructor will pick-up all reusable training literature from the student as is feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTION	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER I	BLOCK TITLE Fundamentals

1 COURSE CONTENT	2 TIME
23. Alternating Current a. From various sine waves, select peak voltage, effective voltage and frequency difference with a minimum of 80% accuracy. STS: 12 Meas: W	1

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-123 (3AER42331-PT-113A), Alternating Current

Training Methods
Self-Instruction (1 hr)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

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NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
24. Capacitance a. Select basic facts, construction characteristic and principles relating to capacitance with a minimum of 80% accuracy. STS: 12 Meas: W	0.5

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3ABR42331-PT-124 (3ABR42331-PT-109), Capacitance

Training Methods
Self-Instruction (0.5 hr)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER I	BLOCK TITLE Fundamentals

1 COURSE CONTENT	2 TIME
25. Inductance a. Select basic facts, construction characteristic and principles relating to inductance with a minimum of 80% accuracy. STS: 12 Meas: W	0.5

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-125 (3AER42331-PT-113C), Inductance

Training Methods
Self-Instruction (0.5 hr)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER I	BLOCK TITLE Fundamentals

1 COURSE CONTENT	2 TIME
26. AC Motors and Control Circuits	10
a. Select components of an AC motor when given their purpose with a minimum of 80% accuracy. STS: 12 Meas: W	(1)
b. Using an electrical diagram, identify a minimum of eight (8) of ten (10) circuit malfunctions when given the cause and circuit condition. STS: 12, 13b, 13c Meas: PC	(3.5)
* c. Using an AC motor control circuit, electrical diagrams and multimeter, locate and record a minimum of four (4) causes for five (5) malfunctions. STS: 12, 13b, 13c, 16c Meas: PC	(5.5)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEBL42331-PT-126 (3AEBL42331-PT-115), AC Motors
3AEBL42331-WB-126 (3AEBL42331-WB-116), AC Motors and Control Circuits Wiring Diagram
3AEBL42331-WB-126A (3AEBL42331-WB-116A), AC Motors and Control Circuits Trouble-shooting

Training Equipment
Multimeter (PSM-37) (1)
Trainer P/N 18 63 2999 Valve Control System (1)
Trainer P/N 18 50 1318 Actuator Valve Assembly Display (1)

Training Methods
Self-Instruction (1 hr)
Performance (9 hrs)

Multiple Instructor Requirements
Supervision, Equipment (3) 26b
Supervision, Equipment (5) 26c

Instructional Guidance
The classroom and/or lab instructor will supervise the student class study and/or lab period, continually administer, evaluate, and critique appraisals, performance exercises, and performance test as each student progresses, record attendance, insure student has correct module materials and equipment, record students progress, maintain each student ATC 156 record, monitor student movement to complete this module between three stations, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. Safety in the labs includes working with or around electrical/mechanical devices. This includes safe use of electrical test equipment, working with and/or construction of 28VDC 5-10 amp circuits and/or working with 115VAC 400 cycle single and/or three phase power. The instructor will provide individual assistance to each student as needed during class/lab periods. Each student must satisfactorily complete the individual appraisals, and/or performance exercise and/or performance tests to satisfy the objectives. The instructor will pick-up all reusable training literature from the student as is feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
27. Solid State Devices a. Select basic facts and principles relating to the construction and operation of solid state devices with a minimum of 80% accuracy. STS: 12 Meas: W	1.5

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3ABR42331-PT-127 (3ABR42331-PT-115), Principles of Solid State Devices

Training Methods
Self-Instruction (1.5 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate, and critique appraisals as each student progresses, record attendance, insure student has correct module materials, record student progress, maintain each students ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER I	BLOCK TITLE Fundamentals

COURSE CONTENT	% TIME
28. Magnetic Amplifiers	4
a. Select components of magnetic amplifiers temperature control circuits when given their purpose with a minimum of 80% accuracy. STS: 12, 13a(3), 13a(4) Meas: W	
b. Identify how a hot and/or cold signal from the bridge affects the components of magnetic amplifier temperature control circuit with a minimum of 80% accuracy. STS: 12, 13a(3), 13a(4) 13b, 13c Meas: W	

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-128 (3AER42331-PT-124), Magnetic Amplifiers

Audio Visual Aids
Transparency, Magnetic Amplifier Circuits CT 73-1584 (1)

Training Methods
Self-Instruction (4 hrs)

Instructional Guidance
The classroom and/or lab instructor will instruct/supervise the student class study and/or lab period, continually administer, evaluate, and critique appraisals, performance exercises, and performance test as each student progresses, record attendance, insure student has correct module material and equipment, record students progress, maintain each student ATC 156 record, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. Safety in the labs includes working with or around electrical/mechanical devices. This includes safe use of electrical test equipment, working with 28VDC 5-10 amp circuits and/or working with 115VAC 400 cycle single phase power. The instructor will provide individual assistance to each student as needed during class/lab periods. Each student must satisfactorily complete the individual appraisal and/or performance exercise and/or performance tests to satisfy the objectives. The instructor will pick up all reusable training literature from the student as is feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE (Modular Self-Paced) Aircraft Environmental Systems Mechanic
BLOCK NUMBER: I	BLOCK TITLE: Fundamentals

1 COURSE CONTENT	2 TIME
29. Trainer Aircraft Air Conditioning System	12.5
a. Select components of a trainer aircraft air conditioning system when given their function and operation with a minimum of 80% accuracy. STS: 13a(1), 13b, 13c, 16a(4) Meas: W	(3.5)
b. Using electrical diagrams, identify a minimum of eight (8) of the ten (10) circuit malfunctions when given the cause and the circuit condition. STS: 13b, 13c Meas: PC	(3.5)
* c. Using a trainer, electrical diagram, and multimeter, troubleshoot system and record a minimum of four (4) causes for five (5) malfunctions. STS: 3a, 13b, 13c, 16c, 16d(1), 16d(2) Meas: PC	(5.5)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-129 (3AER42331-PT-120), Trainer Aircraft Air Conditioning
3AER42331-WB-129 (3AER42331-WB-118), Trainer Aircraft Air Conditioning System Wiring Diagram
3AER42331-WB-129A (3AER42331-WB-118A), Trainer Aircraft Air Conditioning System Troubleshooting

Training Equipment
Multimeter (PSM-37) (1)
Trainer P/N 18 66 3301 Trainer Aircraft Air Conditioning System (2)

Training Methods
Self-Instruction (3.5 hrs)
Performance (9 hrs)

Multiple Instructor Requirements
Supervision, Equipment (3) 29b
Supervision, Equipment (5) 29c

Instructional Guidance
The classroom and/or lab instructor will supervise the student class study and/or lab period, continually administer, evaluate, and critique appraisals, performance exercises, and performance test as each student progresses, record attendance, insure student has correct module materials and equipment, record students progress, maintain each student ATC 156 record, monitor student movement to complete this module between three stations, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. Safety in the labs includes working with or around electrical/mechanical devices. This includes safe use of electrical test equipment, working with and/or construction of 28VDC 5-10 amp circuits and/or working with 115VAC 400 cycle single and/or three phase power. The instructor will provide individual assistance to each student as needed during class/lab periods. Each student must satisfactorily complete the individual appraisals, and/or performance exercise and/or performance tests to satisfy the objectives. The instructor will pick-up all reusable training literature from the student as is feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

30. MT (identified in course chart) 24

31. Measurement and Critique 1.5

a. Measurement Test

b. Test Critique

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE: Aircraft Environmental Systems Mechanic
BLOCK NUMBER: II	BLOCK TITLE: Air Conditioning Systems

1 COURSE CONTENT	2 TIME
1. Fighter Cabin Air Conditioning System	24
a. Associate each bleed air system component with its operation with a minimum of 80% accuracy. STS: 15a Meas: W	(3)
b. Select safety precautions that are applicable to the maintenance of bleed air system, without error. STS: 3a, 15h Meas: W	(1)
c. Identify cabin air conditioning system component operation with a minimum of 80% accuracy. STS: 16a(1), 17a(3) Meas: W	(4)
d. Using a wiring diagram, identify causes for eight (8) of ten (10) given air conditioning system troubles. STS: 13b, 13c, 13d Meas: PC	(4)
* e. Using a multimeter and wiring diagram, perform an operational check and troubleshoot the bleed air system and cabin air conditioning system trainer, locating seven (7) out of nine (9) troubles correctly. STS: 3a, 15d, 16c, 16d(1), 17c, 17d Meas: PC	(12)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-201, Fighter Bleed Air System
3AER42331-PT-201A, Fighter Cabin Air Conditioning System
3AER42331-WB-201, Fighter Cabin Air Conditioning System Wiring Diagram
3AER42331-WB-201A, Fighter Cabin Air Conditioning System Troubleshooting

Audio Visual Aids
Cassette, Tape, Fighter Cabin Air Conditioning System Wiring Diagram
LFC-42-5, Cassette, 8mm Sound, Fighter Cabin Air Conditioning System Wiring Diagram

Training Equipment
Trainer 3305, Fighter Air Conditioning (1)
Multimeter (1)

Training Methods
Self-Instruction (8 hrs)
Performance (16 hrs)

Multiple Instructor Requirements
Equipment, Supervision (4)

Instructional Guidance
The instructor will issue programmed text, workbook, and training equipment to each student. Each student must satisfactorily accomplish each objective before he/she can proceed to the next unit of instruction. After satisfactory completion of PT-201A, direct the student to view Cassette LFC 42-5, 8mm Sound Film, Fighter Cabin Air Conditioning and complete workbook 3AER42331-WB-201, Fighter Cabin Air Conditioning System Wiring Diagram (taped lesson). The instructor will insure that all training equipment used by the student is turned in and properly stored. Where feasible, shut off operating equipment to conserve energy.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE: Aircraft Environmental Systems Mechanic
BLOCK NUMBER: II	BLOCK TITLE: Air Conditioning Systems

1 COURSE CONTENT	2 TIME
2. Rain Removal System	13
a. Relate each rain removal system component to its operation with a minimum of 80% accuracy. STS: 17a(4) Meas: W	(5)
* b. Using a multimeter and wiring diagram, perform an operational check and troubleshoot the rain removal system trainer, locating the cause of six (6) out of eight (8) troubles correctly. STS: 3a, 13c, 17c, 17d Meas: PC	(8)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEB42331-PT-202, Rain Removal System
3AEB42331-WB-202, Rain Removal System Troubleshooting

Training Equipment
Trainer, 3336, Rain Removal System (1)
Multimeter (1)

Training Methods
Self-Instruction (5 hrs)
Performance (8 hrs)

Multiple Instructor Requirements
Equipment, Supervision (4)

Instructional Guidance
The instructor will issue programmed text, workbook and training equipment to each student. Each student must satisfactorily accomplish the objectives before he/she can proceed to the next unit of instruction. The instructor will insure that all training equipment used by the student is turned in and properly stored. Where feasible, shut off all operating equipment to conserve energy.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE: Aircraft Environmental Systems Mechanic
BLOCK NUMBER: II	BLOCK TITLE: Air Conditioning Systems

1 COURSE CONTENT	2 TIME
3. Equipment Air Conditioning System	16
a. Associate each equipment air conditioning component with its operation with a minimum of 80% accuracy. STS: 16a(1) Meas: W	(3)
b. Using a wiring diagram, identify 14 causes for the 10 given equipment air conditioning system troubles. STS: 13b, 13c, 13d Meas: PC	(3)
* c. Using a multimeter and wiring diagram, perform an operational check and troubleshoot the equipment air conditioning system trainer, locating seven (7) out of nine (9) troubles correctly. STS: 3a, 13c, 13d, 16d(2) Meas: PC	(10)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-203, Equipment Air Conditioning System
3AER42331-WB-203, Equipment Air Conditioning System Wiring Diagram
3AER42331-WB-203A, Equipment Air Conditioning System Troubleshooting

Audio Visual Aids
Cassette, Tape, Equipment Air Conditioning System Wiring Diagram
LFC-42-6 Cassette, 8mm Sound, Equipment Air Conditioning System Wiring Diagram

Training Equipment
Trainer 3305, Fighter Air Conditioning (1)
Multimeter (1)

Training Methods
Self-Instruction (3 hrs)
Performance (13 hrs)

Multiple Instructor Requirements
Equipment, Supervision (4)

Instructional Guidance
The instructor will issue programmed text, workbook, and training equipment to each student. Each student must satisfactorily accomplish each objective before he/she can proceed to the next unit of instruction. After satisfactory completion of PT-203, direct the student to view Cassette LFC-42-6, 8mm Sound Film, Equipment Air Conditioning System Wiring Diagram and to complete workbook 3AER42331-WB-203, Equipment Air Conditioning System Wiring Diagram (taped lesson). The instructor will insure that all training equipment used by the student is turned in and properly stored. Where feasible, shut off all operating equipment to conserve energy. Check with each student daily to insure the CTT assignment is being accomplished.

PLAN OF INSTRUCTION/LESSON PLAN PART I	
NAME OF INSTRUCTION	COURSE TITLE: Aircraft Environmental Systems Mechanic
BLOCK NUMBER: II	BLOCK TITLE: Air Conditioning Systems

1 COURSE CONTENT	2 TIME
4. Temperature Control System Tester	7
a. Associate the name of the controls on the temperature control system tester (AN/PSM-21) illustration with its purpose/function, with a minimum of 80% accuracy. STS: 14b Meas: W	(3)
* b. Using a temperature control system tester and multimeter, perform an operational check and troubleshoot the cabin and equipment air conditioning systems trainers, correctly locating three (3) out of four (4) of the assigned troubles. STS: 3a, 14b Meas: PC	(4)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AHH42331-PT-204, Temperature Control System Tester
3AHH42331-WB-204, Temperature Control System Testing

Training Equipment
Trainer 3305, Fighter Air Conditioning (1)
Multimeter (1)
Test Set, AN/PSM-21A (1)

Training Methods
Self-Instruction (3 hrs)
Performance (4 hrs)

Multiple Instructor Requirements
Equipment, Supervision (4)

Instructional Guidance
The instructor will insure that all training equipment used by the student is turned in and properly stored. Where feasible, shut off operating equipment to conserve energy.

5. Measurement and Critique 1.5

a. Measurement

b. Critique

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
II	Air Conditioning Systems

1 COURSE CONTENT	2 TIME
6. Bomber Air Conditioning System	24
a. Relate the name of each bleed air system component to its operation with a minimum of 80% accuracy. STS: 15a Meas: W	(3)
b. Select the safety precautions that are involved in the maintenance of the bleed air system without error. STS: 3a, 15h Meas: W	(1)
c. Relate the name of each cabin air conditioning system component to its operation with a minimum of 80% accuracy. STS: 16a(2) Meas: W	(4)
d. Using a wiring diagram, identify eight (8) causes for the ten (10) given air conditioning system troubles. STS: 13c, 13d Meas: PC	(4)
* e. Using a multimeter and wiring diagram, perform an operational check and troubleshoot the bleed air and cabin air conditioning system trainer, locating a minimum of 11 out of 14 troubles correctly. STS: 3a, 16c, 16d(1) Meas: PC	(12)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-206 (3AER42331-PT-205), Bomber Bleed Air Supply System
3AER42331-PT-206A (3AER42331-PT-205A), Bomber Air Conditioning System
3AER42331-WB-206 (3AER42331-WB-205), Bomber Air Conditioning System Wiring Diagram
3AER42331-WB-206A (3AER42331-WB-205A), Bomber Air Conditioning System Troubleshooting

Audio Visual Aids
Cassette, Tape, Bomber Air Conditioning System Wiring Diagram
LFC 42-7, Cassette, 8mm Sound, Bomber Air Conditioning System Wiring Diagram

Training Equipment
Trainer 2518, Bomber Air Conditioning System (1)
Multimeter (1)

Training Methods
Self-Instruction (8 hrs)
Performance (16 hrs)

Multiple Instructor Requirements
Equipment, Supervision (4)

Instructional Guidance
The instructor will issue programmed text, workbook, and training equipment to each student. Each student must satisfactorily accomplish the objective before he/she can proceed to the next unit of instruction. After satisfactory completion of PT-206A, direct the student to view Cassette, LFC 42-7, 8mm Sound Film, Bomber Air Conditioning System Wiring Diagram and then to complete workbook 3AER42331-WB-206, Bomber Air Conditioning System Wiring Diagram (taped lesson). The instructor will insure that all training equipment used by the student is turned in and properly stored. Where feasible shut off equipment to conserve energy.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE: Aircraft Environmental Systems Mechanic
BLOCK NUMBER: II	BLOCK TITLE: Air Conditioning Systems

COURSE CONTENT	TIME
7. Decade Resistor Functions and Windshield Amplifier Bench Check	2
* a. Using a bench test adapter, decade box, and windshield temperature amplifier, bench check and adjust the windshield temperature amplifier to the specified values. STS: 3a, 14a(2), 17a(4), 17f Meas: PC	(2)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEBL42331-WB-207 (3AEBL42331-WB-207, WB-207A), Decade Resistor Functions and Windshield Temperature Amplifier Bench Check

Training Equipment

Adapter Cabin Temperature 5919 (1)
Decade Box (1)
Control Assembly, Windshield Temperature Amplifier 6032 (1)

Training Methods
Performance (2 hrs)

Multiple Instructor Requirements
Equipment, Supervision (4)

Instructional Guidance
The instructor will issue programmed text and training equipment to each student. Each student must satisfactorily accomplish each objective before he/she can proceed to the next unit of instruction. The instructor will insure that all training equipment used by the student is turned in and properly stored. Where feasible, shut off operating equipment when not in use to conserve energy. Check with each student daily to insure that the CTT assignment is being accomplished.

PLAN OF INSTRUCTION/LESSON PLAN PART I

PLACE OF INSTRUCTION	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
II	Air Conditioning Systems

COURSE CONTENT	TIME
8. Cargo Bleed Air and Anti-Icing System	18
a. Associate the name of each cargo bleed air and anti-icing system component with its operation with 80% accuracy. STS: 15a, 17a(5) Meas: W	(2)
b. Using a wiring diagram, identify four (4) out of five (5) given anti-icing system control circuits troubles. STS: 13b, 13c Meas: W	(8)
c. Using a wiring diagram, identify four (4) out of five (5) given air intake duct anti-icing system control circuit troubles. STS: 13b, 13c Meas: W	(8)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEB42331-PT-208 (3AEB42331-PT-207), Cargo Aircraft Engine Bleed Air System
3AEB42331-PT-208A (3AEB42331-PT-207A), Wing and Empennage Anti-Icing System
3AEB42331-PT-208B (3AEB42331-PT-207B), Engine Air Intake Duct Anti-Icing System

Training Methods
Self-Instruction (18 hrs)

Instructional Guidance
The instructor wil issue programmed text and training equipment to each student. Each student must satisfactorily accomplish each objective before he/she can proceed to the next unit of instruction. The instructor will insure that all training equipment used by the student is turned in and properly stored. When feasible, shut off operating equipment to conserve energy.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
II	Air Conditioning Systems

1 COURSE CONTENT	2 TIME
9. Cargo Air Conditioning System	22
a. Associate the name of each cargo air conditioning system component with its operation with 80% accuracy. STS: 15a, 16a(3) Meas: W	(4)
b. Associate the name of the mercury thermostat temperature control system component with its operation with 80% accuracy. STS: 13a(2), 13c, 16a(3) Meas: W	(4)
c. Using a wiring diagram, identify eight (8) causes for the ten (10) given air conditioning system electrical troubles. STS: 13b, 13c, 13d Meas: PC	(6)
* d. Using a wiring diagram and multimeter, perform an operational check and troubleshoot the cargo air conditioning system trainer, locating a minimum of five (5) out of seven (7) troubles correctly. STS: 3a, 16c, 16d(2) Meas: PC	(8)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-209 (3AER42331-PT-208), Cargo Air Conditioning System
3AER42331-PT-209A (3AER42331-PT-208A), Mercury Thermostat Temperature Control System
3AER42331-WB-209 (3AER42331-WB-208), Cargo Air Conditioning System Wiring Diagram
3AER42331-WB-209A (3AER42331-WB-208A), Cargo Air Conditioning System Troubleshooting

Audio Visual Aids
Transparency, CT 73-260 Mercury Thermostat System

Training Equipment
Trainer, 3021, Cargo Air Conditioning System (1)
Multimeter (1)

Training Methods
Self-Instruction (8 hrs)
Performance (14 hrs)

Multiple Instructor Requirements
Supervision, Equipment (4)

Instructional Guidance
The instructor will issue workbook and training equipment to each student. Each student must satisfactorily accomplish the objectives before he/she can proceed to the next unit of instruction. The instructor will insure that all training equipment used by the student is turned in and properly stored. Check with each student daily to insure the CTT assignment is being accomplished.

10. MT (identified in course chart) 6.0

11. Measurement and Critique 1.5

    a. Measurement

    b. Critique

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
III	. Aircraft Environmental Systems Units

COURSE CONTENT	TIME
3. Tools, Hardware, Safetying Devices, and Wire Repair	18
a. Using a box of handtools, select and match tools with their proper uses with 70% accuracy. STS: 8a Meas: PC	(5)
b. Using display boxes containing items of aircraft hardware, match each item's number to its proper use. 70% of the items must be matched correctly. STS: 10c Meas: PC	(3)
c. Using a trainer and applicable handtools, torque aircraft type (1) nuts according to procedures covered in TO 1-1A-8. STS: 8a, 10c Meas: PC	(1)
d. Using mechanical safetying devices, a trainer, and applicable handtools, safety bolts, clamps, and connectors according to procedures covered in TO 1-1A-8. STS: 3a, 8b, 10c Meas: PC	(5)
e. Using a trainer, applicable tools and equipment, solder wire to connectors and install electrical wiring IAW TO 1-1A-14. STS: 3a, 10c, 10d(1), 10d(2), 10d(3) Meas: PC	(3)
f. Identify the use of general purpose connectors, bonding shielding, and grounding. A minimum of 70% accuracy must be obtained. STS: 10d(1) Meas: W	(1)

Note: Numbers 1 and 2 of Block III have been omitted because of military specific materials.

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-303, Maintenance Tools
3AER42331-WB-303, Torque Wrench Performance
3AER42331-PT-303A, Aircraft Hardware
3AER42331-WB-303A, Safetying Methods, Procedures and Devices
3AER42331-PT-303B, General Purpose Connectors, Bonding, Shielding and Grounding
3AER42331-WB-303B, Wiring Maintenance
3AER42331-WB-303C, Aircraft Handtools
3AER42331-WB-303D, Aircraft Hardware
TO 1-1A-8, Aircraft Structural Hardware
TO 1-1A-14, Aircraft Electric and Electronic Wiring

Audio Visual Aids
Film AVA 503, Soldering and Soldering Iron Preparation
Film AVA 505, Stripping and Crimping

Training Equipment
Trainer 4059, Torque Wrench Application (1)
Trainer 2301, Safetywire (1)
Trainer 4435, Wiring Maintenance (1)
Torque Wrench (1)
Soldering Iron (1)
Applicable Handtools (1)
Display Boxes 4115, Aircraft Bolts (1)
4116, Aircraft Fittings (1)
4117, Aircraft Fasteners (1)
4118, Pliers (1)
4119, Wrench (1)
4120, Sockets (1)
4121, Hammer (1)

Training Methods
Self-Instruction (7 hrs)
Performance (11 hrs)

Instructional Guidance
The instructor will give each student an orientation relative to laboratory procedures, and will conduct individual assistance as required. Students are required to use wire maintenance trainers, safety wire trainers, soldering equipment, and torque wrenches to complete assigned projects. The instructor guides and assists the students and performs progress checks.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
III	Aircraft Environmental Systems Units

1 COURSE CONTENT	2 TIME
4. Maintenance of Moisture Separators a. Match components of the moisture separator to their function and/or operation. 70% of the listed components must be matched correctly. STS: 16a(3) Meas: W b. Using a TO, applicable handtools and equipment, disassemble, inspect, and reassemble a moisture separator with a maximum of two (2) instructor assists. STS: 16b Meas: PC	3

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3ABR42331-PT-304, Operation of an Aircraft Air Conditioning System Moisture Separator
3ABR42331-WB-304, Maintenance of Moisture Separators
T.O. 1C-130A-06, Work Unit Code Manual
T.O. 15A7-2-11-3, Moisture Separator
AFTC Form 349, Maintenance Data Collection Record

Training Equipment
Moisture Separator (1)
Applicable Handtools (1)

Training Methods
Self-Instruction (1 hr)
Performance (2 hrs)

Instructional Guidance
The laboratory instructors will provide assistance on an individual basis as required, and insure that each objective is accomplished. An instructor assist is defined as limited aid such as location of a component, technical direction or explanation, and/or technical order interpretation given a student who can proceed no further on his/her own.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
III	Aircraft Environmental Systems Units

1 COURSE CONTENT	2 TIME
5. Maintenance of Bleed Air Distribution Ducting a. Inspect a section of aircraft ducting and record a minimum of three discrepancies found during the inspection. STS: 15b Meas: PC b. Identify the three (3) types of repairs that can be made on bleed air duct insulation. STS: 15g Meas: W c. Identify three (3) of four (4) methods used to slow corrosion on bleed air ducting. STS: 10a Meas: W d. Match the types of cleaning agents and/or lubricants to their uses. 70% of the items must be matched correctly. STS: 10b Meas: W	3

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3ABR42331-PT-305, Maintenance of Bleed Air Distribution Ducting
3ABR42331-WB-305, Maintenance of Bleed Air Distribution Ducting

Training Equipment
Aircraft Ducting (1)

Training Methods
Self-Instruction (2 hrs)
Performance (1 hr)

Instructional Guidance
The instructor will make sure the workbook and section of aircraft ducting are available for the student to use. Observe student's progress on the objectives and provide individual assistance as necessary. Answer any questions that may arise.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
III	Aircraft Environmental Systems Units

1 COURSE CONTENT	2 TIME
6. Air Turbine Motor Maintenance a. Identify general principles pertaining to the operation of an air turbine motor with a minimum accuracy of 80%. STS: 20a Meas: W * b. Using maintenance data collection forms, ground air cart, and inspection workcards perform an operational check and inspect the air turbine motor with a maximum of two instructor assists. STS: 3a, 3b, 3g, 20b, 20c Meas: PC	3

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3ABR42331-PT-306 (316), Air Turbine Motors
3ABR42331-WB-306 (316), Maintenance of Air Turbine Motors
AFTO Form 26, Inspection Workcard
AFTO Form 349, Maintenance Data Collection Record

Training Equipment
Ear Protectors (1)
Air Turbine Motor (2)
MA-1A Ground Air Cart (2)

Training Methods
Self-Instruction (1 hr)
Performance (2 hrs)

Instructional Guidance
The classroom instructor will observe students in class and insure subject material is completed before testing. Answer any questions that may arise. The laboratory instructor will orient each student to the laboratory situation, and brief students on safety hazards and precautions and conservation of energy and materials. Stress danger areas when working with hot compressed air. Also, insure that each student has ear protectors when working in high intensity noise areas. Observe students performance while completing the workbook, and provide individual assistance as required. Have students record work on maintenance data forms. Assure each objective is covered. An instructor assist is defined as limited aid such as location of a component, technical direction or explanation, and/or technical order interpretation, given to a student who can progress no further on his/her own.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
III	Aircraft Environmental Systems Units

1 COURSE CONTENT	2 TIME
7. Turbine Refrigeration Devices	3
a. Match listed components of a turbine refrigeration device to their operation and/or location with 70% accuracy. STS: 16a(1), 16a(2), 16a(3) Meas: W	

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3ABR42331-PT-307, Turbine Refrigeration Devices

Training Methods
Self-Instruction (3 hrs)

Instructional Guidance
The classroom instructor will insure all necessary material is available for student use. He/she will observe students in class and insure subject material is completed before testing. Answer any questions that may arise.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
III	Aircraft Environmental Systems Units

1 COURSE CONTENT	2 TIME
8. Advanced Fighter/Bomber Air Source Control System	11
a. Match the components of the fighter/bomber air source control system to their operation/function with 70% accuracy. STS: 15a, 16a(1), 16a(2) Meas: W	(1.5)
b. Using a wiring diagram of the figher/bomber air source control system, identify seven (7) of ten (10) system malfunctions correctly. STS: 13b, 13c, 15a, 16a(1), 16a(2) Meas: PC	(5.5)
c. Using a wiring diagram and a multimeter, perform an operational check on the advanced fighter/bomber air conditioning system trainer and troubleshoot four (4) of five (5) malfunctions correctly. STS: 13b, 13c, 13d, 15a, 15b, 15c, 15d, 16a(1), 16a(2) Meas: PC	(4)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEB42331-PT-308, Advanced Fighter/Bomber Air Source Control System
3AEB42331-WB-308A, Advanced Fighter/Bomber Air Source Control System
3AEB42331-WB-308, Advanced Fighter/Bomber Air Source Control System Operational Check and Troubleshooting
AFTO Form 781A, Maintenance Discrepancy and Work Document
AFTO Form 349, Maintenance Data Collection Record
TO 1F-111A-06, Work Unit Code Manual

Training Equipment
Trainer 4024, Advanced Fighter/Bomber Air Conditioning System (2)
Multimeter (1)

Training Methods
Self-Instruction (1.5 hrs)
Performance (9.5 hrs)

Instructional Guidance
The classroom instructor will observe students in class, and insure subject material is completed before testing. Answer any questions that may arise. The laboratory instructor will orient each student to the laboratory situation and brief the students on safety hazards and precautions and conservation of energy and materials. Observe students performance while completing the workbook and provide individual assistance as required. Have students record work on maintenance data forms. Assure each objective is covered.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE: Aircraft Environmental Systems Mechanic
BLOCK NUMBER: III	BLOCK TITLE: Aircraft Environmental Systems Units

1 COURSE CONTENT	2 TIME
9. Advanced Fighter/Bomber Air Conditioning System	15
a. Match the components of the advanced fighter/bomber air conditioning system to their function and/or operation with 70% accuracy. STS: 13b, 16a(1), 16a(2) Meas: W	(4)
b. Using a wiring diagram of the advanced fighter/bomber air conditioning system, identify seven (7) of ten (10) systems malfunctions from symptoms given. STS: 13b, 13c, 13d, 16a(1), 16a(2) Meas: PC	(4)
c. Using a wiring diagram and a multimeter perform an operational check and troubleshoot the fighter/bomber air conditioning system trainer locating the cause of four (4) of the five (5) malfunctions given. STS: 13b, 13c, 13d, 16a(1), 16a(2), 16c, 16d(1) Meas: PC	(4)
* d. Using a schematic diagram, source of hot pressurized air, and the fighter/bomber environmental systems capsule, perform an operational check, and troubleshoot the system locating the cause of four(4) of five (5) malfunctions given. STS: 3g, 15a, 15c, 15h, 16b, 16c, 16d(1), 17b, 17c, 17d Meas: PC	(3)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEBR42331-PT-309, Fighter/Bomber Air Conditioning System
3AEBR42331-PT-309A, Fighter/Bomber Temperature Control System
3AEBR42331-WB-309A, Fighter/Bomber Temperature Control Wiring Diagram
3AEBR42331-WB-309, Component, Identification, Operational Check and Troubleshooting
3AEBR42331-WB-309B (3AEBR42331-WB-311), Functional Check of Air Conditioning System

Training Equipment
Trainer, 4024, Advanced Fighter/Bomber Air Conditioning System (2)
Trainer CT5, Environmental Systems (4)
Ear Protectors (1)
Multimeter (1)

Training Methods
Self-Instruction (4 hrs)
Performance (11 hrs)

Instructional Guidance
The classroom instructor will observe students in class and insure subject material is completed before testing. Answer any questions that may arise. The laboratory instructor will orient each student to the laboratory situation, and brief students on safety hazards and precautions and conservation of energy and materials. Stress danger areas when working with hot compressed air. Also, insure that each student has ear protectors when working in high intensity noise areas. Observe students performance while completing the workbooks, and provide individual assistance as required. Have students record work on maintenance data forms. Assure each objective is covered.

10. Measurement Test and Test Critique 2

a. Measurement Test

b. Test Critique

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
I.I	Aircraft Environmental Systems Units

1 COURSE CONTENT	2 TIME
11. Advanced Fighter/Bomber Windshield Clearing System	10
a. Match components of the fighter/bomber windshield clearing system to their function and/or operation with 70% accuracy. STS: 17a(4) Meas: W	(1)
b. Using a wiring diagram, identify seven (7) of ten (10) causes for system malfunctions in the fighter/bomber windshield clearing system. STS: 13b, 13c, 13d Meas: PC	(5)
c. Using a wiring diagram and multimeter, perform an operational check and troubleshoot malfunctions on the fighter/bomber windshield clearing system trainer locating the cause for four(4) of the five (5) malfunctions given. STS: 13b, 13c, 13d, 17b, 17c, 17d Meas: PC	(4)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-311 (3AER42231-PT-310), Fighter/Bomber Windshield Clearing System
3AER42331-WB-311A (3AER42231-WB-310A), Fighter/Bomber Windshield Clearing System
3AER42331-WB-311 (3AER42231-WB-310), Advanced Fighter/Bomber Windshield Clearing System
AFTO Form 781A, Maintenance Discrepancy and Work Document
AFTO Form 349, Maintenance Data Collection Record
TO 1F-111A-06, Work Unit Code Manual

Training Equipment
Trainer 4024, Advanced Fighter/Bomber Air Conditioning System (2)
Trainer CT5, Environmental Systems (4)
Multimeter (1)

Training Methods
Self-Instruction (1 hr)
Performance (9 hrs)

Instructional Guidance
The classroom instructor will observe students in class, and insure subject material is completed before testing. Answer any questions that may arise. The laboratory instructor will brief each student on safety hazards and precautions and conservation of energy and materials. Observe students performance while completing the workbooks and provide individual assistance as required. Have students record work on maintenance data collection forms. Assure each objective is covered.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
III	Aircraft Environmental Systems Units

1 COURSE CONTENT	2 TIME
12. Maintenance of Air Control Units	14
a. Match the components of air control units to their function and/or operation with 70% accuracy. STS: 11e, 15a, 16a(1), 16a(2) Meas: W	(4)
b. Using the applicable TO, electric/pneumatic component trainer, multimeter, and the necessary tools, bench check selected air control units with a maximum of two instructor assists for each air control unit checked. STS: 3a, 14c, 15f, 15h, 16a(1), 16b, 16c, 16f, 16g Meas: PC	(5)
c. Using a schematic, match the components of an airflow control and shutoff valve to their function and/or operation with 70% accuracy. STS: 15a, 16a(1), 16a(2) Meas: W	(3)
d. Using the applicable TO, electric/pneumatic component trainer and the necessary tools, bench check an airflow control and shutoff valve with a maximum of two instructor assists. STS: 14c, 15f, 16g Meas: PC	(2)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-312, Air Control Valves
3AER42331-WB-312, Bench Testing Electric Motor Actuated Valves
3AER42331-PT-312A, Principles of Airflow Control and Shutoff Valve
3AER42331-WB-312A, Airflow Control and Shutoff Valve
TO 9P5-5-59-43, Two and one-half inch diameter Pneumatic Shutoff Valve
TO 9P5-14-3-3, Two and one-half inch diameter Modulating Electric Air Shutoff Valve
TO 15A2-2-52-83, Motor Actuated Butterfly Shutoff Valve Assembly
TO 1B-52G-06, Work Unit Code Manual
TO 15A2-2-92-3, Power Operated Butterfly Valve
TO 1C-130A-06, Work Unit Code Manual
TO 15A2-2-20-193, Two and one-half inch diameter Shutoff Air Flow Regulator
AFTO Form 349, Maintenance Data Collection Record
AFTO Form 350, Repairable Item Processing Tag

Training Equipment
Trainer 3038, Electric/Pneumatic Component (1)
Applicable Aircraft Valves (1)
Applicable Handtools (1)
Multimeter (1)

Training Methods
Self-Instruction (7 hrs)
Performance (7 hrs)

Instructional Guidance
The classroom instructor will observe students during class, and provide individual assistance as required. Insure subject material is completed before testing, and answer any questions that may arise. Assure that the objectives are covered. The laboratory instructor will orient the students to the laboratory situation, and brief them on safety hazards and precautions. Provide individual assistance as required, and assure objectives are covered. An instructor assist is defined as limited air such as location of a component, technical direction or explanation, and/or technical order interpretation, given to a student who can progress no further on his own.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
III	Aircraft Environmental Systems Units

1 COURSE CONTENT	2 TIME
13. Anti-G Suit System a. Match the major components of the anti-G suit valve to their function and/or operation with 70% accuracy. STS: 17a(1) Meas: W b. Using a ground laboratory test kit, electric-pneumatic component trainer, the necessary handtools, and the applicable TO, bench check an anti-G suit valve with a maximum of two instructor assists. STS: 14c, 17b, 17d, 17f, 17g Meas: PC c. Inspect an anti-G suit valve in accordance with the TO, and list four (4) of five (5) discrepancies. STS: 17b Meas: PC	2

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEB42331-PT-313, Principles of Anti-G System
3AEB42331-WB-313, Maintenance of Anti-G Suit Valve
TO 9P5-3-12-3, Anti-G Suit Valve

Training Equipment
Trainer 4058, Anti-G Suit Valve (1)
Trainer 3038, Electric-Pneumatic Component (1)
Test Kit P/N 10670, Ground Laboratory (1)
Applicable Handtools (1)

Training Methods
Self-Instruction (1 hr)
Performance (1 hr)

Instructional Guidance
The classroom instructor will insure that the cutaway display of the anti-G suit valve is available for student use. Provide individual assistance as required, and insure subject material is completed before testing. Answer any questions that may arise. Assure that the objective is covered. The laboratory instructor will brief students on safety hazards and precautions, and provide individual assistance as required, and assure the objectives are accomplished. An instructor assist is defined as limited aid such as location of a component, technical direction or explanation, and/or technical order interpretation, given a student who can proceed no further on his/her own.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
III	Aircraft Environmental Systems Units

1 COURSE CONTENT	2 TIME
14. Canopy Seal System	4
a. Match the major components of the canopy seal system to their function and/or operation with 70% accuracy. STS: 17a(2) Meas: W	
b. Using the electric-pneumatic components trainer, the necessary handtools and the applicable TO, bench check a canopy seal pressure regulator with a maximum of two instructor assists. STS: 14c, 17f, 17g Meas: PC	
c. Inspect a canopy seal air regulator in accordance with the TO, and list two (2) of three (3) discrepancies. STS: 17b Meas: PC	

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-314, Canopy Seal System
3AER42331-WB-314, Maintenance of Canopy Seal Regulators
TO 16R1-4-2-3, Overhaul Instructions with Illustrated Parts Breakdown Canopy Seal Pressure Regulator

Training Equipment
Trainer 3038, Electric-Pneumatic Component (1)
Canopy Seal Regulator (1)
Applicable Handtools (1)

Training Methods
Self-Instruction (1 hr)
Performance (3 hrs)

Instructional Guidance
The classroom instructor will observe students during class and provide individual assistance as required. Insure subject material is completed before testing. Assure the objective is covered. The laboratory instructor will insure safety precautions are followed and provide individual assistance when necessary. An instructor assist is defined as limited aid such as location of a component, technical direction or explanation, and/or technical order interpretation, given to a student who can progress no further on his/her own.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
III	Aircraft Environmental Systems Units

1 COURSE CONTENT	2 TIME
15. Pressurization Systems	12
a. Match cabin pressurization system terms and/or principles of operation to their definitions. Seven (7) of ten (10) items must be matched correctly. STS: 18a Meas: W	(3)
b. Match the components of cabin pressurization systems to their function and/or operation. 70% of the components must be matched correctly. STS: 18a Meas: W	(9)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AERL42331-PT-315, Pressurization Principles
3AERL42331-PT-315A, Fighter Pressurization System
3AERL42331-PT-315B, Bomber Pressurization System
3AERL42331-PT-315C, Variable Isobaric Pressurization

Audio Visual Aids
Film LFC 4212, Pressurization Principles
Film LFC 4213, Fighter, Bomber and Cargo Pressurization Systems

Training Methods
Self-Instruction (12 hrs)

Instructional Guidance
The classroom instructor will inform the students that they are to watch training films LFC 4212 and LFC 4213 before starting on the programmed texts. The instructor will insure all necessary material is available for student use. He/she will observe students in class and insure subject material is completed before testing. Answer any questions that may arise.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
III	Aircraft Environmental Systems Units

1 COURSE CONTENT	2 TIME
16. Cabin Pressure Leakage Check	4
a. Using a diagram of the control panel of a cabin pressure leakage tester, match the controls and gages to their purpose and/or function. 70% of the controls and gages must be matched correctly. STS: 14f Meas: PC	
* b. Using a cabin pressure leakage tester, the necessary tools, and the applicable TO, perform a cabin pressure leakage test on the CT-5 trainer with a maximum of three instructor assists. STS: 3g, 14f, 18b, 18c, 18d, 18h Meas: PC	

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AEBL2331-WB-316 (3AEBL2231-WB-317), Operation of MB-3 Leakage Tester
3AEBL2331-WB-316A (3AEBL2231-SW-317), Cabin Pressure Leakage Check
TO 33A4-4-10-1, Portable Electric Motor Driven Pressurized Cabin Leakage Tester Type MB-3
TO 1F-111A-2-2-1, Airframe and Related System

Training Equipment
Trainer CT-5 Environmental Systems or Aircraft (4)
Safety Net (4)
Warning Signs (4)
MB-3 Cabin Leakage Tester (4)
Tool Box (4)

Training Methods
Performance (4 hrs)

Instructional Guidance
The instructor will orient students to the laboratory situation and brief students on danger areas and noise protection. Provide individual assistance as required, and assure objectives are accomplished. An instructor assist is defined as limited aid such as location of a component, technical direction or explanation, and/or technical order interpretation given to a student who can proceed no further on his own.

17. [illegible] (identified in course chart) 8

18. Measurement and Critique 2

a. Measurement Test

b. Test Critique

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechani

BLOCK NUMBER	BLOCK TITLE
IV	Utility Systems and Flight Line Maintenance

1 COURSE CONTENT	2 TIME
1. Gaseous Oxygen Systems	4
a. Relate four (4) of five (5) low and high pressure gaseous oxygen system components to their purpose. STS: 21a(1) Meas: W	(.5)
b. Relate four (4) of five (5) demand oxygen system components with their purpose. STS: 21a(1) Meas: W	(1)
c. Relate four (4) of five (5) pressure demand oxygen system components to their purpose. STS: 21a(1) Meas: W	(1)
d. Relate four (4) of five (5) continuous flow oxygen system components to their purpose. STS: 21a(1) Meas: W	(1)
e. Select, without error, safety precautions pertaining to the use and handling of gaseous oxygen. STS: 21h Meas: W	(.5)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AER42331-PT-401, Principles of Gaseous Oxygen and Safety
3AER42331-PT-401A, Low and High Pressure Gaseous Oxygen Systems
3AER42331-PT-401B, Demand Oxygen Equipment
3AER42331-PT-401C, Pressure Demand Oxygen Equipment
3AER42331-PT-401D, Continuous Flow Oxygen Equipment

Training Methods
Self-Instruction (4 hrs)

Instructional Guidance
The instructor will instruct/supervise the student class study period, continually administer, evaluate and critique appraisals as each student progresses, insure the student has correct module materials, record student progress, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
IV	Utility Systems and Flight Line Maintenance

1 COURSE CONTENT	2 TIME
2. Liquid Oxygen Systems	4
a. Relate four (4) of five (5) basic liquid oxygen system components to their purpose. STS: 21a(2) Meas: W	(.5)
b. Relate four (4) of five (5) advance liquid oxygen system components to their purpose. STS: 21a(2) Meas: W	(1)
c. Relate four (4) of five (5) liquid oxygen quantity indicating system components to their purpose. STS: 21a(2) Meas: W	(1)
d. Relate four (4) of five (5) oxygen system servicing equipment components to their purpose. STS: 21a(2) Meas: W	(.5)
e. Select, without error, safety precautions involved in handling liquid oxygen. STS: 21h Meas: W	(.5)
f. From a list of statements, identify four (4) of five (5) statements concerning the correct usage of CTKs and FOD prevention program. STS: 8c Meas: W	(.5)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

3ABR42331-PT-402, Characteristics and Safe Handling of Liquid Oxygen
3ABR42331-PT-402A, Aircraft Liquid Oxygen System Basic System with Single Function Valves
3ABR42331-PT-402B, Aircraft Liquid Oxygen System Advanced Design with Dual Function Valves
3ABR42331-PT-402C, Liquid Oxygen Quantity Indicating Systems
3ABR42331-PT-402D (3ABR42331-PT-403), Oxygen Systems Servicing and Equipment
3ABR42331-HO-402, Foreign Object Damage Prevention and Composite Tool Kits

Training Methods

Self-Instruction (4 hrs)

Instructional Guidance

The instructor will instruct/supervise the student class study period, continually administer, evaluate and critique appraisals as each student progresses, insure the student has correct module materials, record student progress, counsel student as needed regarding academic and non-academic reasons, monitor break and clean-up periods. The instructor will provide individual assistance to each student as needed during class. Each student must satisfactorily complete the appraisal to satisfy the objective(s). The instructor will pick up all reusable training literature from the student(s) as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
IV	Utility Systems and Flight Line Maintenance

COURSE CONTENT	TIME
3. Inspection and Maintenance of Liquid Oxygen Systems	16
* a. Using a trainer, go-no-go gage, inspection workcard and work unit code manual, inspect the oxygen system. One (1) instructor assist is permissible. STS: 3a, 3c, 21b Meas: PC	(2)
* b. Using a field tester and oxygen regulator, perform an operational check of the oxygen regulator. One (1) instructor assist is permissible. STS: 3a, 3c, 14d(2) Meas: PC	(2)
* c. Using a trainer and leakage test equipment, perform an operational and leakage test on a liquid oxygen system with one (1) instructor assist. STS: 3a, 3c, 14d(2), 14e, 21b, 21c, 21d, 21h Meas: PC	(2)
* d. Using a capacitance tester, trainer, oxygen converter, and necessary tools, bench check the converter capacitance system with one (1) instructor assist permissible. STS: 3a, 3c, 14d(3), 21f, 21h Meas: PC	(3)
* e. Using the TTU/162E tester, perform an operational check and troubleshoot a liquid oxygen converter for malfunction. One (1) instructor assist is permissible. STS: 3a, 3c, 3g, 14d(1), 21d, 21h Meas: PC	(3)
* f. Using the necessary tools and equipment, remove, repair and replace selected components of an oxygen system. One (1) instructor assist can be given for each component. STS: 3a, 3c, 3g, 21g Meas: PC	(4)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AHR42331-WB-403, Oxygen Systems Laboratory Projects
TO 15X1-1, Oxygen Systems and Equipment
TO 1T-38A-06, Work Unit Code Manual
TO 33D2-10-4-6-1, Operation, Servicing, Maintenance and Repair Instructions - Liquid Oxygen Tester TTU/162E
TO 33D2-6-182-1, Operation and Servicing Instructions Capacitance Liquid Oxygen Quantity Indicating Systems Test Set TF20-1
AFTO Form 26, Inspection Workcard
AFTO Form 349, Maintenance Data Collection Record

Training Equipment
Go-no-go Gage (2)
Oxygen Safety Equipment (1)
MH-1 Leak Tester (2)
Tool Kit (2)
Sonic Leak Detector (2)
Oxygen Converter (2)
TTU/162E Converter Tester (2)
TTU/28E Master Gage (2)
Hot Purge Kit (2)
MH-2 Leak Tester (2)
TF-20-1 Capacitance Tester (2)
MA-1 Service Cart (2)
TMU/27 Service Cart (2)
Trainer 3251 Liquid Oxygen (2)
Trainer 1762 Oxygen Systems (2)
Trainer 3193 Liquid Oxygen Converter (2)
Tester, Field (2)

Training Methods
Performance (16 hrs)

Instructional Guidance
The lab instructor will supervise the lab period, continually administer, evaluate and critique performance exercises and performance test as each student progresses, insure student has correct module materials and equipment, record students progress, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. The instructor will provide individual assistance to each student as needed during lab projects. Each student must satisfactorily complete the individual performance exercises and/or performance tests to satisfy the objectives. The instructor will pick up all reusable training literature from the student as feasible. Turn off all power as applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module. An instructor assist is defined as limited aid; such as location of a component, technical direction or explanation, and/or technical order interpretation given a student who can proceed no further on his/her own. A detected safety violation (DSV) is an automatic failure for that objective.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
IV	Utility Systems and Flight Line Maintenance

1 COURSE CONTENT	2 TIME
4. Cryotainer Systems Maintenance	24
a. Relate eight (8) of ten (10) cryotainer components to their purpose. STS: 26a Meas: W	(3.5)
* b. Observe the safety precautions relative to cryotainers. STS: 26h Meas: PC	(2)
* c. Using a KC-15 vacuum pump, vacuum micron gage and 50 gallon cryotainer, evacuate cryotainer. Three (3) instructor assists permissible. STS: 3a, 3b, 3c, 26b Meas: PC	(4)
* d. Using a TMU-27M LOX cart, GSU-62M purging unit and workbook purge cryotainer. Four (4) instructor assists permissible. STS: 3a, 3b, 3c, 3g, 26c Meas: PC	(3.5)
* e. Using a cryotainer, tools, inspection workcard, inspect cryotainer and components, locating three (3) discrepancies and record on AFTO Form 349. One instructor assist, per form, is permissible. STS: 3a, 3c, 26d Meas: PC	(3)
* f. Using leak teck solution, ultrasonic leak detector, safety equipment and cryotainer, perform operational and leak checks. One instructor assist permissible. STS: 3a, 3c, 26e Meas: PC	(4)
* g. Using assigned cryotainer and proper tools, remove and reinstall three (3) of the eleven (11) selected components. One instructor assist is permissible. STS: 3a, 3c, 26f Meas: PC	(4)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3ABR42331-PT-404, Cryotainer Construction and Maintenance
3ABR42331-WB-404, Inspection and Maintenance of Cryotainers
AFTO Form 349, Maintenance Data Collection Record
TO 00-25-06-2-2, Work Unit Code Manual (Support Equipment)

Training Equipment
Cryotainer Storage Tank (2)
Purge Unit (2)
Vacuum Pump (2)
Micron Gage (2)
Applicable Tools (1)

Training Methods
Self-Instruction (3.5 hrs)
Performance (20.5 hrs)

Instructional Guidance
The classroom and/or lab instructor will supervise the student class study and/or lab period, continually administer, evaluate and critique appraisals, performance exercises and performance tests as each student progresses, insure student has correct module materials and equipment, record students progress, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. The instructor will provide individual assistance to each student as needed during class/lab period. Each student must satisfactorily complete the individual appraisals and/or performance exercise and/or performance tests to satisfy the objectives. An instructor assist is defined as limited aid such as the location of a component, technical direction or explanation and/or technical order interpretation for the student who can proceed no further on his/her own. A detected safety violation is an automatic failure for this objective. Stress danger areas when working with hot compressed air and high pressure gases. Also, insure that each student has ear protectors when working in high intensity noise areas. The instructor will pick-up all reusable training literature from the student as feasible. Turn off power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

MIR: One instructor is required for every four (4) students performing in this station. Students in this station use purge units and vacuum pumps (the purge unit produces hot compressed air) and safety equipment to complete assigned projects. Students also work with high pressure gas cylinders. Multiple instructors are required for 20.5 hours of this lesson.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
IV	Utility Systems and Flight Line Maintenance

1 COURSE CONTENT	2 TIME
5. Life Raft Inflation Equipment	5.5
a. Relate four (4) of five (5) components of life raft inflation equipment to their purpose. STS: 23a Meas: W	(1)
b. Relate four (4) of five (5) components of life raft recharging equipment to their purpose. STS: 23b Meas: W	(1)
* c. Identify the safety precautions relative to recharging and discharging life raft cylinders with 100% accuracy. STS: 3a, 3c, 23f Meas: W.	(1)
* d. Using the inflation cylinder recharging equipment, scales and tools, prepare and service a life raft cylinder to within 1/100 lbs of its specified weight. STS: 3a, 3c, 3g, 23b, 23e, 23f Meas: PC	(1)
* e. Using an assigned life raft cylinder and tools, inspect the valve head assembly and cylinder. One instructor assist is permissible. STS: 3a, 3c, 23c Meas: PC	(1.5)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

3AERR42331-PT-405 (3AERR42331-PT-404), Life Raft Inflation Equipment
3AERR42331-PT-405A (3AERR42331-PT-404A), Recharging Equipment for and Maintenance of Life Raft Cylinders
3AERR42331-WB-405 (3AERR42331-WB-404), Inspection, Operation and Recharging Life Raft Cylinders
TO 34Y14-14-2-13-1, Operation, Servicing and Repair Instructions, Carbon Dioxide Servicing Unit

Training Equipment

Carbon Dioxide Recharging Unit (2)
Scale-Dial and Beam (2)
Life Raft Inflation Cylinder (2)
Tool Kit (2)

Training Methods

Self-Instruction (2.5 hrs)
Performance (3 hrs)

Instructional Guidance

The classroom and/or lab instructor will supervise the student class study and/or lab period, continually administer, evaluate and critique appraisals, performance exercises, and performance test as each student progresses, insure student has correct module materials and equipment, record students progress, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. The instructor will provide individual assistance to each student as needed during class/lab periods. Each student must satisfactorily complete the individual appraisals, and/or performance exercise and/or performance tests to satisfy the objectives. An instructor assist is defined as limited aid such as the location of a component, technical direction or explanation, and/or technical order interpretation given a student who can proceed no further on his/her own. A detected safety violation is an automatic failure for that objective. The instructor will pick-up all reusable training literature from the student as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic

BLOCK NUMBER	BLOCK TITLE
IV	Utility Systems and Flight Line Maintenance

1 COURSE CONTENT	2 TIME
6. Fire Extinguisher System Maintenance	8
a. Associate four (4) of the five (5) components of the fire extinguishing directional system with their purpose. STS: 22a(1), 22a(2) Meas: W	(2)
b. Select the safety precautions, without error, involved in the handling of fire extinguishing agents, toxic compounds, explosive squibs and high pressure gases. STS: 22i Meas: W	(1)
* c. Using a fire extinguishing trainer, inspection workcard and maintenance data collection forms, inspect the fire extinguishing system, recording a minimum of five (5) discrepancies on appropriate forms. One instructor assist, per form, is permissible. STS: 22b Meas: PC	(1)
* d. Using a trainer, perform an operational check of the fire extinguishing system, with one instructor assist. STS: 22c, 22i Meas: PC	(1)
* e. Using a fire extingvishing trainer and multimeter, trouble-shoot the system for malfunctions, locating four (4) of five (5) causes correctly. STS: 22d, 22i Meas: PC	(2)
* f. Using squibs, container provided, and igniter circuit tester, bench check two (2) squibs for proper resistance value, with one instructor assist, while observing all safety precautions pertaining to explosive squibs. STS: 22f, 22i Meas: PC	(.5)
g. Relate four (4) of the five (5) components of the fire extinguishing servicing unit to their purpose. STS: 22g, 22h Meas: W	(.5)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AERR42331-PT-406 (3AERR42331-PT-407A), Aircraft Fire Extinguishing Liquid Agent Systems
3AERR42331-PT-406A (3AERR42331-PT-407B), Aircraft Fire Extinguishing System Recharging Equipment
3AERR42331-WB-406 (3AERR42331-WB-407), Inspection and Operational Check of a Fire Extinguishing System
3AERR42331-WB-406A (3AERR42331-WB-407A), Troubleshooting Fire Extinguishing and Engine Isolation Systems
3AERR42331-WB-406B (3AERR42331-WB-407B), Bench Check Fire Extinguishing Components
AFTO Form 26, Inspection Workcard
AFTO Form 349, Maintenance Data Collection Record

Audio Visual Aids
Film AVA C-141 Fire Extinguishers

Training Equipment
Trainer 3180 Fire Extinguishing System (2)
Container and squib (2)
Multimeter (2)
Igniter Tester (2)

Training Methods
Self-Instruction (3.5 hrs)
Performance (4.5 hrs)

Instructional Guidance
The classroom and/or lab instructor will supervise the student class study and/or lab period, continually administer, evaluate, and critique appraisals, performance exercises, and performance tests as each student progresses, insure student has correct module materials and equipment, record student progress, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. The instructor will provide individual assistance to each student as needed during class/lab periods. Each student must satisfactorily complete the individual appraisals, and/or performance exercises, and/or performance tests to satisfy the objectives. An instructor assist is defined as limited aid such as location of a component, technical direction, or explanation and/or technical order interpretation given a student who can proceed no further on his/her own. A detected safety violation is an automatic failure for that objective. The instructor will pick up all reusable training literature as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR

COURSE TITLE: Aircraft Environmental Systems Mechanic

BLOCK NUMBER: IV

BLOCK TITLE: Utility Systems and Flight Line Maintenance

1 COURSE CONTENT	2 TIME
7. Liquid Refrigeration Systems and Components	13.5
a. Relate four (4) of five (5) components of a liquid coolant system to its operation. STS: 25a(1) Meas: W	(1)
b. Relate four (4) of five (5) components of a liquid cycle refrigeration system to their purpose. STS: 25a(2) Meas: W	(2.5)
c. Select the safety precautions relative to liquid refrigerants without error. STS: 25h Meas: PC	(1)
* d. Using an inspection workcard, maintenance data collection forms, and trainer, inspect a liquid refrigeration system, recording a minimum of two (2) discrepancies. One instructor assist, per form, is permissible. STS: 3a, 3c, 3g, 7d, 25b Meas: PC	(2.5)
* e. Using a trainer, perform an operational check of a liquid refrigerant system with one instructor assist. STS: 3a, 3c, 3g, 25c, 25h Meas: PC	(2.5)
* f. Using a trainer and schematic, troubleshoot a liquid refrigerant system, with one instructor assist. STS: 3a, 3c, 3g, 25d Meas: PC	(2)
* g. Using a trainer, vacuum pump, leak detector, tool kit and Freon cylinders, bench check and repair system components, with one instructor assist. STS: 25f, 25g, Meas: PC	(2)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
3AERR42331-PT-407 (3AERR42331-PT-409), Liquid Coolant Systems
3AERR42331-PT-407A (3AERR42231-PT-409A), Liquid Cycle Refrigeration System
3AERR42331-WB-407 (3AERR42331-WB-409), Liquid Refrigerant System Maintenance
AFTO Form 26, Inspection Workcard
AFTO Form 349, Maintenance Data Collection Record

Audio Visual Aids
Film TF 5624B, Refrigeration, Expansion Valves, Thermostatic Valve Operation
Film TF 5536A, Servicing the MA-3 Air Conditioner
Film TF 5536B, Refrigeration

Training Equipment
Trainer 4369 Liquid Refrigeration System (2)
Vacuum Pump (2)
Leak Detector (2)
Freon Cylinders (2)
Tool Kit (1)

Training Methods
Self-Instruction (4.5 hrs)
Performance (9 hrs)

Instructional Guidance
The classroom and/or lab instructor will supervise the student class study and/or lab period, continually administer, evaluate and critique appraisals, performance exercises, and performance tests as each student progresses, insure student has correct module material and equipment, record students progress, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. The instructor will provide individual assistance to each student as needed during the class/lab periods. Each student must satisfactorily complete the individual appraisals, and/or performance exercises and/or performance tests to satisfy the objectives. An instructor assist is defined as limited aid such as the location of a component, technical direction or explanation, and/or technical order interpretation given a student who can proceed no further on his/her own. A detected safety violation is an automatic failure for this objective. The instructor is to insure each student wears eye protection during the handling of Freon to prevent possible blinding of the student. The instructor will pick up all reusable training literature from the student as feasible. Turn off all power when applicable to conserve energy and resources. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

8. Measurement and Critique 1.5
   a. Measurement Test
   b. Critique

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mecha

BLOCK NUMBER	BLOCK TITLE
IV	Utility Systems and Flight Line Maintenance

1 COURSE CONTENT	2 TIME
9. Flight Line Maintenance - Inspections	16
* a. Using an inspection workcard, available aircraft, applicable technical orders, and maintenance data collection forms, inspect selected components of the bleed air distribution system, recording a minimum of two (2) discrepancies on appropriate forms. One instructor assist, per form is permissible. STS: 3a, 3c, 3g, 4b, 4d, 7c, 15b Meas: PC	(3)
* b. Using an inspection workcard, available aircraft, applicable technical orders and maintenance data collection forms, inspect selected components of the air conditioning system, recording a minimum of five (5) discrepancies on appropriate forms. One instructor assist, per form, is permissible. STS: 3a, 3c, 3g, 4b, 4d, 7c, 16b Meas: PC	(4)
* c. Using an inspection workcard, available aircraft, applicable technical orders, and maintenance data collection forms, inspect selected components of the auxiliary air system, recording a minimum of two (2) discrepancies on appropriate forms. One instructor assist is permissible. STS: 3a, 3c, 3g, 4b, 4d, 7c, 17b Meas: PC	(3)
* d. Using an inspection workcard, available aircraft, applicable technical orders and maintenance data collection forms, inspect selected components of the pressurization system, recording a minimum of two (2) discrepancies on appropriate forms. One instructor assist, per form, is permissible. STS: 3a, 3c, 3g, 4d, 7c, 18b Meas: PC	(3)
* e. Using an inspection workcard, available aircraft, applicable technical orders and maintenance data collection forms, inspect selected components of the liquid oxygen system, recording a minimum of five (5) discrepancies on appropriate forms. One instructor assist is permissible, per form. STS: 3a, 3c, 3g, 4b, 4d, 7c, 21b Meas: PC	(3)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
Applicable Technical Orders
AFTO Form 349, Maintenance Data Collection Record
AFTO Form 26, Inspection Workcard
3ABR42331-HO-410, FOD Prevention (Replaced by 3ABR42331-HO-402)

Training Equipment
Available Aircraft (4)
Tool Kit (2)
MH-2 Leakage Tester (1)
T-38A Heat, Pressurization and Anti-Ice

Training Methods
Performance (16 hrs)

Multiple Instructor Requirements
Safety, Equipment and Supervision (3) 10a, 10b, 10c, 10d, 10e

Instructional Guidance
The lab instructor will supervise the lab period, continually administer, evaluate, and critique performance exercises as each student progresses, insure student has correct module materials and equipment, record student progress, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. The instructor will provide individual assistance to each student as needed during the lab period. Each student must satisfactorily complete the individual performance exercise and/or performance test to satisfy the objectives. The instructor will pick up all reusable training literature from the student as feasible. Turn off all power when applicable to conserve energy and resources. An instructor assist is defined as limited aid, such as the location of a component, technical direction or explanation, and/or technical order interpretation given a student who can proceed no further on his/her own. A detected safety violation is an automatic failure for that objective. Insure students wear ear protectors in high intensity noise areas. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

MIR: One instructor is required for each four (4) student performing in this station. This is due to the physical layout of the hangar, the amount of maintenance performed by the students and the safety involved while working on the flight line. Students in this station inspect, perform maintenance and operational checks on selected components of the T-38A environmental systems. Multiple instructors are required for 16 hours of this module.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Aircraft Environmental Systems Mechanic
BLOCK NUMBER	**BLOCK TITLE**
IV	Utility Systems and Flight Line Maintenance

1 COURSE CONTENT	2 TIME
10. Flight Line Maintenance, Removal and Replacement of System Components	24
a. Using available aircraft, applicable technical orders, hand-tools and maintenance data collection forms, remove and replace selected components of the bleed air distribution system. One instructor assist is permissible. STS: 3a, 3b, 3c, 3g, 4b, 7c, 8a, 10c, 15c, 15e, 15h Meas: PC	(5)
b. Using available aircraft, applicable technical orders, hand-tools and maintenance data collection forms, remove, replace and perform an operational check on selected components of the air conditioning system. Two instructor assists are permissible. STS: 3a, 3b, 3c, 3g, 4b, 7c, 8a, 10c, 15h, 16c, 16e Meas: PC	(6)
c. Using available aircraft, applicable technical order, hand-tools and maintenance data collection forms, remove and replace selected components of the auxiliary air system. One instructor assist is permissible. STS: 3a, 3b, 3c, 3g, 4b, 7c, 8a, 10c, 15h, 17c, 17e Meas: PC	(5)
d. Using available aircraft, applicable technical orders, hand-tools and maintenance data collection forms, remove and replace selected components of the pressurization system. One instructor assist is permissible. STS: 3a, 3c, 3g, 4b, 7c, 8a, 8b, 10c, 18e Meas: PC	(3)
e. Using available aircraft, applicable technical orders, hand-tools and maintenance data collection forms, remove and replace selected components of the liquid oxygen system. One instructor assist is permissible. STS: 3a, 3c, 3g, 4b, 7c, 8a, 10c, 21e Meas: PC	(5)

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
Applicable Technical Orders
AFTO Form 350, Repairable Item Processing Tag
AFTO Form 349, Maintenance Data Collection Record
AFTO Form 781A, Maintenance Discrepancy Work Document

Training Equipment
Available Aircraft (4)
Tool Kit (1)
Ear Protectors (1)

Training Methods
Performance (24 hrs)

Multiple Instructor Requirements
Safety, Equipment and Supervision (3) 11a, 11b, 11c, 11d, 11e

Instructional Guidance
The lab instructor will supervise the lab period, continually administer, evaluate, and critique performance exercises and performance tests as each student progresses, insure student has correct module materials and equipment, record students progress, counsel student as needed regarding academic and non-academic reasons, monitor breaks and clean-up periods, insure student complies with safety practices IAW AFR 127-101. The instructor will provide assistance to each student as needed during the lab period. Each student must satisfactorily complete the individual performance exercise and/or performance test to satisfy the objectives. An instructor assist is defined as limited aid such as the location of a component, technical direction or explanation, and/or technical order interpretation given a student who can proceed no further on his/her own. The instructor will pick up all reusable training literature from the student as feasible. Turn off all power when applicable to conserve energy and resources. A detected safety violation is an automatic failure for that objective. Insure students wear ear protectors in high intensity noise level area. The instructor will refer to Part II Teaching Guide for detailed instructions on this module.

MIR: One instructor is required for each four (4) students performing in this station. This is due to the physical layout of the hangar, the amount of maintenance performed by the students and the safety involved while working on the flight line. Students in this station inspect, perform maintenance and operational checks on selected components of the T-38A environmental systems. Multiple instructor are required for 24 hours of this module.

11.	MT (identified in course chart)	14
12.	Course Critique and Graduation	.5

Environmental Pneudraulics Branch
Chanute AFB, Illinois

3ABR42132-HO-101
3ABR42231-HO-101A
26 October 1972

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As time permits, study the reference materials listed in this bibliography for the base library. After studying the materials listed, you will possess a much broader knowledge of the course material than would otherwise be possible during normal classroom instruction.

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Prepared by Sheppard TTC

TECHNICAL TRAINING

STUDY SKILLS

June 1973

AIR TRAINING COMMAND

Designed For ATC Course Use

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Target Population: Students entering 3ABR courses.

Special Materials: Dictionary

INSTRUCTIONS

123

Study this programmed text alone at your own pace. If parts of the text are not clear the first time you read them, review the material.

The material in this text is presented in small steps called frames. You respond to each frame by either writing answers, completing statements, or selecting answers. The correct answers follow each frame and are separated from the text and questions by vertical lines (||||||||||||||||||||).

Use a card or heavy paper as a mask to cover the correct answers. Place the card on the page and slide it down the page until you uncover the vertical lines (see example below). Then read the information and answer the questions. After you have answered the questions, check your answers by uncovering the correct response. If you respond incorrectly to any frame, *reread* and *study the frame until you understand it.*

Example:

Air Training Command initials are _____.

||||||||||||||||||||

ATC - (answer under mask)

MASK

OBJECTIVES

1. List three prerequisites that should be met before starting to study.

2. Identify the lesson objective, main heading, and subheadings in a narrative written in study guide format.

3. Scan a reading assignment and write questions to be answered while reading.

4. Underline the topic sentence in each of several paragraphs.

5. Outline the key points contained in several paragraphs.

6. Write a summary paragraph for a three paragraph reading assignment.

7. Underline the correct answers to the questions concerned with the reading assignment material.

8. Identify the facts or parts in a given illustration.

9. List and explain the steps to be followed for the SQ3R method of study.

10. List three requirements for effective listening during a discussion or lecture.

11. List three rules for taking notes during a discussion or lecture.

12. Write an acceptable outline for taking notes during a discussion or lecture.

13. Locate specific words in a dictionary, write or state their meaning, and pronounce them correctly.

14. Alphabetize a group of words.

15. Find or state the page number of a subject appearing in a Table of Contents.

16. Listen and take notes identifying the four main points of an oral presentation.

INTRODUCTION

Good study habits are essential to effective use of study time. Your study time can be used more effectively if you practice the proven procedures covered in this text. Remember, good study habits never develop accidentally.

To improve your study habits, *study* the information in this text, don't just read it. Practice the procedures given here each time you study to help form good study habits.

PREPARE TO STUDY

OBJECTIVE

List three prerequisites that should be met before starting to study.

INTRODUCTION

Learning doesn't just happen; it must be planned. The time you spend in preparing for study is time well invested. There are at least three important things you need to do before you begin to study. You must develop a positive attitude toward study; you must set a definite time each day for study; and you must choose a specific place to study.

INFORMATION

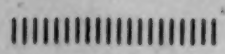
Attitude

Attitude is defined as feeling or emotion. Your attitude toward study influences how well you learn. You must have a positive attitude toward study before you can learn. If you have a feeling of opposition toward study, you will learn little or nothing at all. Sometimes your feeling of opposition toward study stems from some problem not connected with your study. In these cases, you should identify the problem and attempt to correct it. Then your attitude toward study should improve.

Figure 1. The Problem

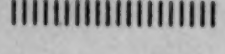
Use Mask on Next Page!

Before you begin to learn, you must have a _____ _____ toward study.



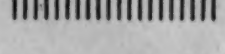
positive attitude

That which most affects learning from study is possibly the student's _____ .



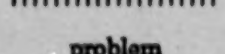
attitude

If you have a feeling of opposition toward study, you should try to determine the cause of this _____ .



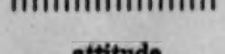
attitude

Sometimes your feeling of opposition toward study is due to a _____ not connected with your study.



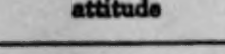
problem

Take time to solve the problem and your _____ toward study will improve and learning will be easier.



attitude

The feeling you have toward study is your _____ .



attitude

Use Mask on Next Page!

Time To Study

You will be more satisfied with yourself and of more value to the Air Force if you will develop good study habits. You should set aside a regular time each day for study.

When is the best time for you to study? This depends on you and your schedule. There are two study periods you need for effective study.

First, set aside a specific time prior to class to study the material to be covered in class. This should be the same time each day.

Second, set aside some time each day after class to review the material covered in class. A large portion of information lost is forgotten within 24 hours after you hear or read it.

Once you set aside these same periods each day for study, *stick to it.*

Do not schedule study immediately prior to bedtime. The end of the study period may find you asleep.

You should set aside a _____ _____ each day for study.

IIIIIIIIII

regular time or specific time

Figure 2. Study Time

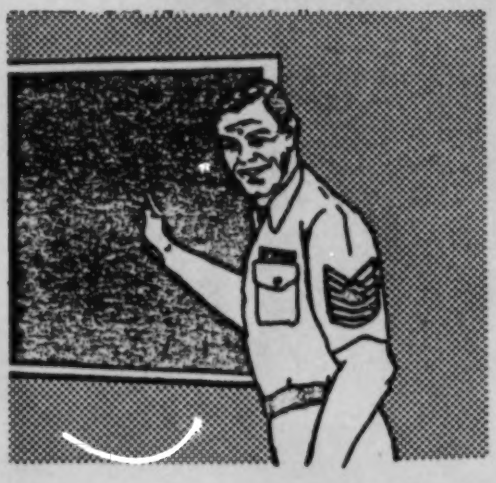


Figure 3. The Instructor Can't Do It All

Instead of studying now and then when it is convenient, you should set aside a _____ _____ each _____ for studying.

IIIIIIIIIIIIIIIIIII

specific or regular time day

Use Mask on Next Page!

You should eliminate as many distracters as possible. Distracters are things such as television, radio, odors, pictures, books not relating to the subject to be studied, hunger, and uncomfortable clothing. Room temperature can also be a distracter if it is too hot or too cold. If you cannot elimnate distracters, you must learn to ignore them.

Make an effort to begin studying as soon as you sit down in your selected place for study. This will soon become part of your good study habits.

Figure 5. Distractions are Numerous

A good study habit is to have a selected _____ to study.

||||||||||||||||||||

place

You should attempt to study in the same place and at the same _____ every _____.

||||||||||||||||||||

time day

Your place for study should be _____ and _____.

||||||||||||||||||||

quiet comfortable

If your place of study is too comfortable you may be inclined to go to _____.

||||||||||||||||||||

sleep

Use Mask on Next Page!

130

Your study can be interrupted by _____.

||||||||||||||||||||

distracters

Television, radio, uncomfortable clothing, hunger, and odors are all _____.

||||||||||||||||||||

distracters

You should eliminate or ignore all _____.

||||||||||||||||||||

distracters

Your place of study should be _____, _____, and free of _____.

||||||||||||||||||||

quiet comfortable distracters

Good study habits are essential to effective use of study time. There are three needs to consider before beginning to study. You must have a _____ _____ toward study; have a definite _____ to study; and select the best available _____ for study.

||||||||||||||||||||

positive attitude time place

NOTE: By now you should be accustomed to the use of the mask. So you will no longer be reminded to use it throughout the text.

STUDY TO LEARN

OBJECTIVES

Given a reading assignment consisting of 10 paragraphs:

1. Identify the objectives, main headings, and subheadings.
2. Scan the paragraphs and write at least one question from each paragraph.
3. Underline the topic sentence in each paragraph.
4. Write an outline containing all key points.
5. Write a summary paragraph for the entire assignment.
6. Underline the correct answers to questions you wrote as you scanned the material.

INTRODUCTION

Learning is a science based on definite rules and principles. Regardless of your background and ability, if you follow the rules and principles of learning, you have a tremendous advantage over those who ignore them.

A good study plan starts with determining the intent (objective) of the lesson. Since authors use different styles of writing, you must learn to recognize the style and identify the lesson objective. Air Training Command (ATC) study guides and student texts all follow prescribed formats. This should make it easier for you to determine the lesson objective and identify key points.

INFORMATION

ATC manuals establish guidelines for writing student texts and study guides. Objectives at the beginning of each major section describe what you should know or be able to do after completing the lesson. Headings, subheadings and sub-subheadings are used to break the material down into smaller units. Summary paragraphs and questions are normally used at the end of major sections to aid you in reviewing the material.

You can determine the intent of a lesson in an ATC student text by reading the _____ at the beginning of the major section.

IIIIIIIIIIIIIIIIIIII

objective

132

Read the objective of Practice Lesson #1, "Preparing for Disaster," on page 15. The disasters identified in this objective are _____, _____, and _____.

!!!!!!!!!!!!!!!!!!!!

floods, tornadoes, hurricanes

After reading the lesson objective, look for the main headings, subheadings and sub-subheadings. These follow the word INFORMATION and give you an idea of how the lesson is layed out. They also give you a chance to mentally form some questions about the subject.

Check Practice Lesson #1 on page 15 for the heading and subheadings and list them below.

a. Heading -

b. Subheadings -

!!!!!!!!!!!!!!!!!!!!

a. Heading - Natural Disasters

b. Subheadings - (1) Floods; (2) Tornadoes; (3) Hurricanes; (4) Emergency Survival Supplies

---

One way to determine lesson layout and to start forming questions is to look for the _____, _____ and _____.

!!!!!!!!!!!!!!!!!!!!

headings, subheadings, sub-subheadings

The next step in the process of learning by reading is to scan the lesson and jot down questions to answer when you read the text. Remember, scanning is *NOT* reading the text word for word, but picking out a sentence here and there to get a general idea of the subject. This enables you to write questions to answer while reading. An example of a question on Practice Lesson #1 is:

What public utilities are disrupted during a severe flood?

You would answer this question while reading the lesson.

Scan Practice Lesson #1, "Preparing for Disaster," on page 15 and write at least five questions to be answered when you're reading the lesson.

Questions

1.

2.

3.

4.

5.

||||||||||||||||||||

Sample Questions:

1. What guidelines are given in preparing for an approaching flood?
2. How can a tornado be recognized?
3. What hurricane warnings are given by the Weather Bureau?
4. What type of emergency survival supplies should be stocked?
5. Which is more essential for survival, food or water?

A properly written paragraph has a topic sentence. The topic sentence states the main idea of the paragraph. The remainder of the paragraph is supporting information and summary.

You can find the general idea of the material in a paragraph by reading the _____ sentence.

||||||||||||||||||||

topic

A method of determining the content of a paragraph is to look for the _____.

||||||||||||||||||||

topic sentence

134

Read the part of Practice Lesson #1 concerning Hurricanes (page 16) and underline the topic sentence in each paragraph.

There are _____ paragraphs with a total of _____ topic sentences.

4 4

The article on hurricanes has the topic sentence as the first sentence of each paragraph. You should have underlined the first sentence of each paragraph.

Underlining key points is a good way to make lesson review easier if the text is yours to keep. If the book must be returned, a good method to use is to outline the material in the following manner:

1. First Main Idea
   a. Fact and reasoning supporting 1
      (1) Fact and reasoning to support a
      (2) Additional fact and reasoning to support a
         (a) Support for (2)
         (b) Additional support for (2)
            1. Support for (b)
            2. Additional support for (b)
   b. Additional fact and reasoning to support 1
      (1) Support for b
      (2) Additional support for b
      (3) Etc.
2. Second Main Idea
   a. Fact and reasoning supporting 2
   b. Etc.

The outline can be more or less detailed depending on the complexity of the material and what you need for review.

Use the part of Practice Lesson #1 covering Emergency Survival Supplies and complete the following outline:

1. Emergency Survival Supplies
   a.

Your outline should be similar to this:

1. Emergency Survival Supplies
   a. Basic supplies
      (1) Food
         (a) Two-week supply at home
         (b) Three-day supply in automobile
         (c) No refrigeration or cooking
      (2) Water or other liquids
   b. Comfort supplies
      (1) Food seasonings
      (2) Flashlight
      (3) Radio
      (4) First aid
      (5) Games and books

Another way to help yourself remember the material is to write a summary paragraph for small sections of the material. Read the summary paragraph for Practice Lesson # 1.

Two ways to aid retention of material and provide for review is to make an _____ or write a _____ paragraph.

outline summary

Using that part of the practice lesson covering Tornadoes, write a summary paragraph for these three paragraphs. Your summary paragraph should have at least one sentence for each paragraph.

SUMMARY: Tornadoes

Your summary should be similar to the following:

Tornadoes

A tornado is usually a funnel-shaped cloud spinning rapidly and extending from a thundercloud. Heavy rain and hail accompany the tornado. It can destroy almost everything in its path. In case of an approaching tornado, you should seek shelter in a cellar, a cave, an underground excavation or under furniture against inside walls. Buildings should have doors or windows open on the side opposite the approaching tornado.

Some lessons have review questions at the end of a section or chapter. These questions are there for your convenience. Answering them aids in your review of the material. The questions usually concern key points of the lesson.

Key points of a lesson may be determined by looking up the answers to _____ _____.

review questions

One way to identify _____ _____ of a lesson is to underline review question answers in the text.

key points

The following review questions cover part of the practice lesson "Preparing for Disaster." Locate and underline the answers to the questions.

1. What should you do with canned goods in the event of flood?
2. If a tornado is approaching, where should you seek shelter?
3. What is a hurricane alert?
4. How many days food supply is considered adequate for emergencies?
5. How much liquid per day does a person need for survival over an extended period of time?

You must learn to study before you study to learn. Study methods have many names, but they follow a pattern similar to this section on "Study to Learn." You should determine what the lesson is about and what you need to know after studying the lesson. Scan the lesson for headings and topic sentences. Read the lesson and answer questions you developed while scanning. Review what you have read. If you follow this procedure, you will have a better understanding of the lesson.

NOTE: Go to page 18 and 19.

Practice Lesson #1

PREPARING FOR DISASTERS

OBJECTIVE

State at least three precautions you should take against each of the following: floods, tornadoes, and hurricanes.

INTRODUCTION

The word "disaster" means a sudden and extraordinary misfortune. It implies an unforeseen mischance bringing with it destruction of property and/or life. You will study some advanced planning and precautions you can take to reduce the serious effects of natural disasters if they occur within your neighborhood.

INFORMATION

NATURAL DISASTERS

Floods

Severe floods may be infrequent, but their effects can be disastrous. There may be a breakdown in telephone and other communication; the disruption of water, electric, and gas services; food spoilage and difficulty in food distribution; the outbreak of disease; costly property damage; and loss of life. When the waters have subsided, debris must be cleared away, services restored, and property rebuilt.

The Office of Civil Defense has given some guidelines in preparing for an approaching flood. You should pack dishes, canned goods, and household supplies in baskets and other containers. Store these and movable furniture on the top floor or the highest part of the house. Disconnect all electrical appliances and motors. If possible move them to safety. Also, turn off gas appliances. When the above actions have been taken, leave as early as you can and take an ample supply of food and water with you.

Tornadoes

A tornado is usually observed as a funnel-shaped cloud spinning rapidly and extending toward the earth from the base of a thundercloud. An hour or two before the tornado strikes, dense, turbulent, thunderstorm clouds will form. They will appear to bulge down. These clouds often have a greenish-black color. Rain and hail often precede the tornado and heavy rain usually falls after it has passed.

Tornadoes are very destructive. The violent winds associated with a tornado can uproot trees, destroy buildings, and create a serious hazard from objects blown through the air. Also, the differences in air pressure within the funnel may lift large objects or cause buildings to collapse.

To know what to do when a tornado is approaching may mean the difference between life or death. The National Weather Service has furnished some guidelines for people to follow when a tornado is approaching. You should keep a radio or television tuned to a local station for information about the tornado. Do not call the Weather Service because you might tie up the telephone line that is needed for emergency calls. Seek shelter such as a cellar, cave, or underground excavation. If such is not available, lie flat in a ditch or earth depression. If you are inside a building, stay away from windows and outside walls. Seek cover under heavy furniture and against inside walls. Doors and windows on the side of the house away from the approaching tornado may be opened to help equalize the air pressure to

prevent the collapse of the building. If you are in open country, move at right angles to the tornado to get out of its path. Above all, remain calm so your thinking and reasoning will be straight.

Hurricanes

Hurricanes form over the ocean and build in intensity as they move over the water. They are very destructive because of the high speed and circular movement of the wind accompanying them. The destructiveness of the wind is not noticeable while the hurricane is out at sea, but becomes apparent as it moves inland. Also, most hurricanes are accompanied by heavy rains. This results in destruction to property exposed to the rain.

As soon as there are definite indications that a hurricane is forming, the Weather Service begins issuing advisory reports. Hurricanes are given names by the Weather Service, such as Beulah, Carla, etc. A *hurricane alert* means that there is no immediate danger but that everyone should stand by for further reports and be ready to take precautionary action if necessary. A *storm warning* may be issued to warn some coastal sections that winds and tides will be dangerous, so that preliminary precautions can be taken. A *hurricane warning* means to take all precautions immediately against the full force of the storm.

The Weather Service issues advisories, alerts, storm warnings, and hurricane warnings every six hours, or oftener if needed. To keep the public informed of the progress of a storm when it is near the mainland, the Weather Service issues bulletins for press, radio, and television every hour or so. State and local civil defense and cooperating Government agencies disseminate warnings by every available means.

The Weather Service has furnished guidelines for you to follow if you are near or in the path of a hurricane. Keep your radio or television tuned to the local station for reports and warnings. It is well to keep a battery-operated radio for use in case of electrical power failure. You may use your car radio. Get away from low-lying beaches or locations which may be covered by high tides or storm waves. If the building you are in is well built and is out of danger of high tides, it is possibly the safest place for you. Board up the windows with good material and fasten them securely. Store extra food and water. The food should not require refrigeration. Since city water service will likely be disrupted, clean the bathtub, jugs, bottles, and cooking utensils and fill them with drinking water. Secure everything that might be blown away or torn loose. Garbage cans, garden tools, porch furniture, and other loose objects become instruments of destruction in the strong winds. It is well to fill the gasoline tank in your car. If power is off, gasoline pumps may not be operative. Check the condition of your flashlight or other emergency lights and be sure they are operative. Remain calm. Your ability to meet emergencies will inspire and help others.

Emergency Survival Supplies

We are always vulnerable to the ravages of nature. Every wise family or individual should prepare for emergencies. If you remember your mother's pantry, it was stocked with food for any emergency, whether it was unexpected company or being snowed in by a winter storm. Such preparation might mean the difference between comfort and hardship; even between survival and starvation in case of an extended disaster.

An adequate supply of food and water is one of the basic preparations for emergencies. A two-week supply of food in your home and a three-day survival kit in your automobile is considered adequate.

Select foods that do not require refrigeration or cooking. Put them in packages suitable for one meal for yourself or for the family group. This makes for easier serving, prevents leftovers that might spoil, and you can plan a variety of foods for each meal.

Water, or other liquid, is essential. Water is more essential than food. Each individual can live on a quart of liquid per day for an extended time. However, one gallon per individual per day will allow for limited bathing.

Other items that may not be essential but will still make conditions more comfortable are salt, sugar, matches, cooking utensils, paper supplies, battery radio, flashlight, first-aid supplies, blankets, pails, garbage containers, etc. Games and items for entertainment are handy items to have along as well as a Bible for religious needs.

SUMMARY

Floods, tornadoes, and hurricanes can cause severe disasters through the destruction of property and/or life. Floods usually result in the spoilage of many items, spread of diseases, and disruption of public services. Both tornadoes and hurricanes cause the above-mentioned destructions as well as damage to property and/or life through violent winds and heavy rains. You should follow the guidelines furnished by the National Weather Service in both the early and immediate preparations for such disasters. Items stored for use in the event of a disaster should be checked periodically and kept in a usable condition.

ILLUSTRATIONS

OBJECTIVE

Identify the facts or parts in a given illustration.

INTRODUCTION

Charts, graphs, drawings, and pictures are used to clarify what the author is writing about. Good illustrations eliminate the need for long and involved descriptions. As a student, you will be required to use information from illustrations in your studies.

INFORMATION

The line drawing of a reservoir accumulator shown in figure 6 is a frequently used type of illustration. Note that the shaded areas represent pressure, return, and air charge. The balloons (circles with numbers) have arrows pointing to parts that are identified below the drawing. This helps you identify parts and liquid and airflow. For instance, number 4 points to a check valve and the shaded area which runs through the check valve is a return line.

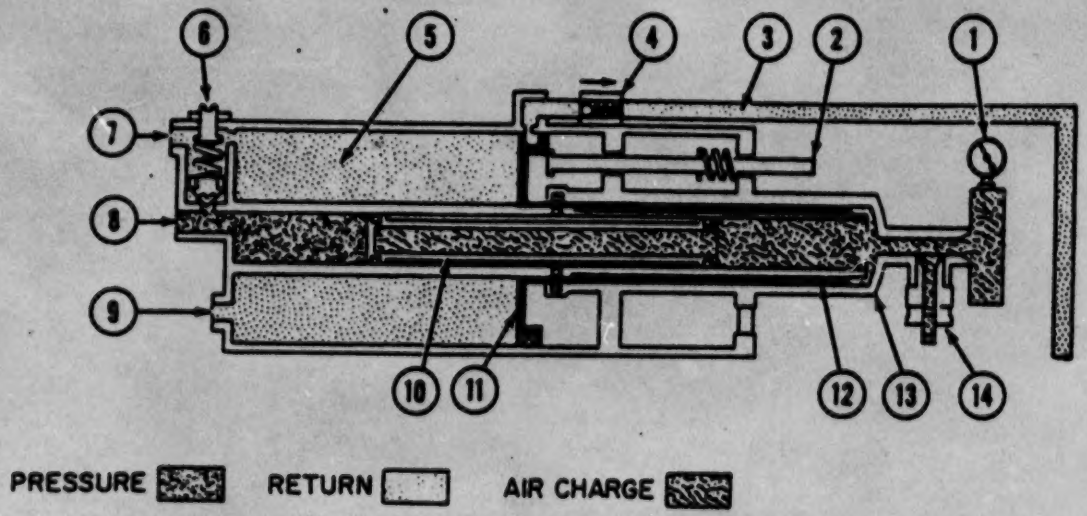


Figure 6. Reservoir Accumulator

141

Number 6 identifies a _____ _____ and the three shaded areas represent _____, _____, and _____ _____.

relief valve pressure, return, air charge

The reservoir piston is identified by number _____ and the shaded area to the left of it is representing a _____.

11 return

Another type of illustration is used in figure 7. This figure is a pictorial of a pressure gage with the parts named on the illustration.

The type tube used in the pressure gage is a _____ tube.

bourdon

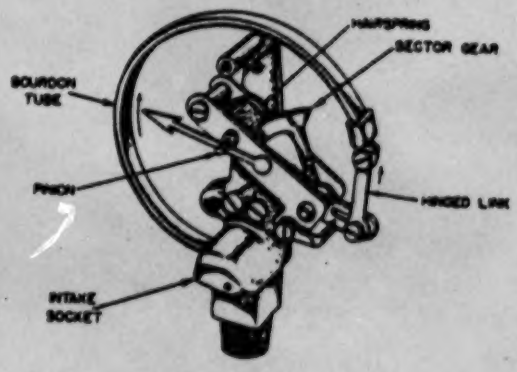


Figure 7. Pressure Gage

Illustrations may be simple or complex. They have one purpose—to clarify the written text. Illustrations are one of your greatest aids to effective study.

THE SQ3R METHOD

OBJECTIVE

List and explain the steps to be followed for the SQ3R method of study.

INTRODUCTION

There are many names for planned methods of study. One is the SQ3R method which has five steps. These steps must be done in the proper sequence for best results. The steps are:

S = Survey - Survey the material.

Q = Question - Ask yourself questions concerning what the lesson is about.

R = Read - Read the material carefully and look for answers to your questions.

R = Recite - Recite to yourself and answer your questions.

R = Review - Think about the lesson and reread areas which aren't clear in your mind.

The SQ3R is a _____ _____ of study.

||||||||||||||||||||

planned method

Which of the following statements are true?

a. A planned method of study helps you get more out of your study time.

b. SQ3R = Survey, Question, Read, Recite, and Reject.

c. The SQ3R is a planned method of study.

d. The steps of the SQ3R method of study have no recommended sequence.

||||||||||||||||||||

a and c

The first step of the SQ3R method is the survey step. This step is to determine the general content of the lesson. To survey the lesson, read the lesson objective first. Then read the headings, subheadings, and sub-subheadings. Read the summary and review questions at the end of the lesson. Then scan each paragraph for the topic sentence.

To determine the general content of the lesson without concerning yourself with specific details, you should _____ the lesson.

||||||||||

survey

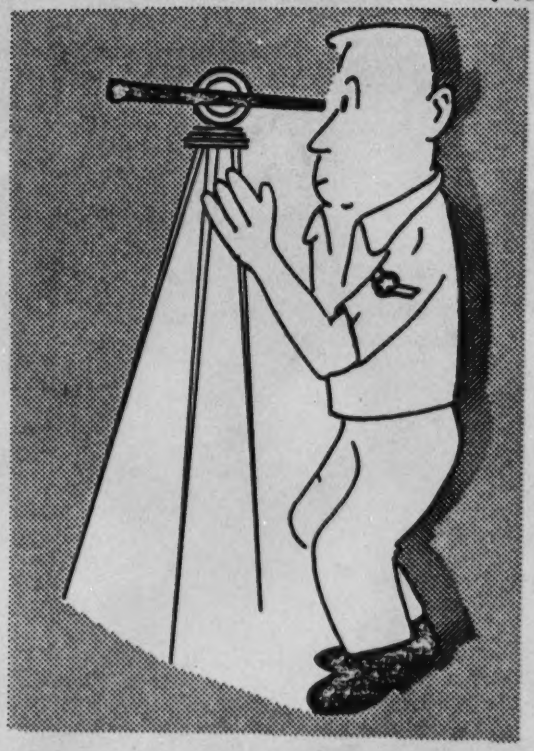


Figure 8. S = Survey

Which of the following statements is true?

a. The best way to survey a lesson is to read all of the text.

b. In surveying the lesson you should first read the objective, headings, subheadings, and sub-subheadings.

c. Summaries should only be read when reviewing the lesson.

||||||||||||||||||||

b

Summaries and review questions should be read for the first time during the _____ step.

||||||||||||||||||||

survey

---

144 Topic sentences aid in the _____ step.

||||||||||||||||||||

survey

Scanning is the best way to perform the survey step. Running the eyes rapidly down a page is called _____.

||||||||||||||||||||

scanning

List at least four things to do when surveying a lesson.

1.
2.
3.
4.
5.

||||||||||||||||||||

1. Read the objective.
2. Read the headings, subheadings, sub-subheadings.
3. Read the summary.
4. Read the review questions.
5. Read the topic sentences.

Survey Practice Lesson #2 on pages 29 and 30. DO NOT READ THE LESSON—only survey it. In the spaces below, list the title, objective, heading and subheadings of the lesson.

Title: _____

Objective: _____

Heading: _____

Subheadings: _____

_____

_____

_____

_____

_____

Title: Principles of Learning

Objective: List the six principles of learning and describe the function of each.

Heading: The Learning Process

Subheadings: Will to Learn
Action
Attention
Organization
Understanding
Review

After surveying a lesson, you should devise questions to answer about the subject. A good method is to rewrite each heading and subheading into a question. For example, if the heading is "Pollution," you could devise the following questions:

What is pollution?

What causes pollution?

What can be done about pollution?

In some cases you may not be able to answer all your questions from the lesson text but the questions will give direction and purpose to your study.

Figure 9. Q = Question

Rewriting each heading and subheading into a question is a good way to perform the _____ step of the SQ3R method of study.

IIIIIIIIIIIIIIIIIIII

question

Which of the following statements are true?

a. You should read the material before devising questions.

b. The "Q" in SQ3R represents "qualify."

c. Devising questions will aid in studying the lesson.

d. The lesson should be surveyed before devising questions.

IIIIIIIIIIIIIIIIIIII

c and d

146

Your study will have better direction and purpose if you perform the _____ step by rewriting the headings and subheadings into _____.

||||||||||||||||||||

question questions

Perform the question step of the SQ3R method of study using Practice Lesson #2.

Questions:

||||||||||||||||||||

The following are typical questions:

1. What is the Learning Process?
2. What does "Will to Learn" mean?
3. What does "Action" have to do with the learning process?
4. How does "Attention" affect the learning process?
5. How does "Organization" affect the learning process?
6. How can I increase my understanding of material I read?
7. What advantage can I gain from review?

Two down and three to go. You should now know how to survey (S) and question (Q). The 3R stands for Read, Recite, and Review.

The next step in the SQ3R method is to read the text *carefully*. Don't skip from here to there hunting the answers to the questions you devised in the question step. Look for the answers as you read each paragraph. Be sure to study each illustration. Start at the beginning of the lesson and read all the material.

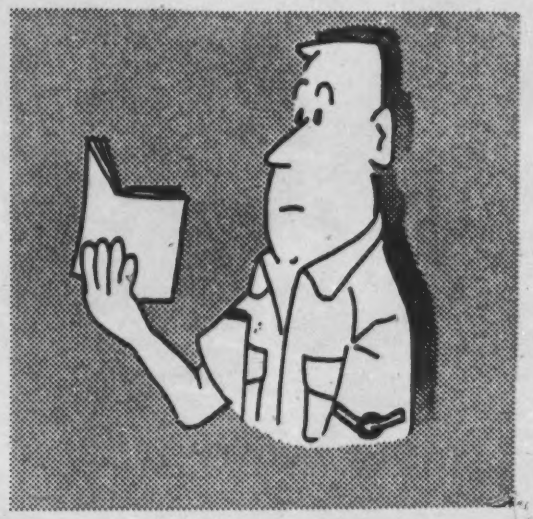


Figure 10. R = Read

Which of the following statements is true?

a. You should look for answers to your questions as you read the lesson.

b. Graphs and tables are supplementary material and may be read if you have time.

c. Disregard the questions you wrote in the previous step until you have read the lesson twice.

IIIIIIIIIIIIIIIIIIII

a

The third step of the SQ3R method of study is to _____ carefully all the material and look for _____ to the _____ you devised in the previous step.

IIIIIIIIIIIIIIIIIIII

read answers questions

Recite, the second "R," requires rephrasing the lesson in your own words. When you finish a paragraph or section, lean back, look away from your book and restate in your own words what the author said. It is best if you recite verbally, whether aloud or under your breath. This aids your understanding of the lesson because you *read* it first, then you *say* it and *hear* it.

You will increase your understanding of the lesson if you can _____ the material in your own words.

||||||||||

recite

Figure 11. R = Recite

Which of the following statements are true?

a. Reciting aloud will help to organize the material in your mind.

b. If a person reads well, he wastes time if he stops to recite the material in his own words.

c. You will understand the lesson better if you rephrase the material in your own words.

d. It is childish for an adult to recite aloud.

||||||||||||||||||||

a and c

The 3Rs of the SQ3R method of study are _____ , _____ , and _____.

||||||||||||||||||||

read, recite, review

Now, using the questions you devised and wrote down on page 24, perform the read and recite steps on Practice Lesson #2, page 29.

The third "R" is Review. The review step is so important to understanding that at least as much time should be spent reviewing as was spent on the survey, question, read, and recite steps combined. To begin your review, close your book, sit back, and think about the material you have studied. This is called reflective thinking. If, during reflective thinking, there is some material that isn't clear and fully understood, go back and reread that material. Then repeat the reflective thinking process. Remember, you should spend at least half of your study time on the review step.

The third R in the SQ3R planned method of study stands for _____.

Figure 12. R = Review

IIIIIIIIIIIIIIIIIIII

review

Which of the following statements are true?

a. If you read the lesson carefully, there is no need to spend a lot of time in reviewing.

b. A good review can be made by leafing through the material.

c. The best way to review is to first close your book, sit back, and think over what you've read.

d. The time spent in the review step should be as much or more than the time spent on all other steps combined.

e. Organizing the material into your own words causes you to do reflective thinking.

IIIIIIIIIIIIIIIIIIII

c, d and e

If the material is not clear during the _____ step, you should reread it.

IIIIIIIIIIIIIIIIIIII

review

---

150 Close your book, sit back and think about the material you have studied. This is _____.

reflective thinking

The steps of the SQ3R planned method of study are _____, _____, _____, _____, and _____.

survey, question, read, recite, review

NOTE: Go to page 31.

Practice Lesson #2

PRINCIPLES OF LEARNING

OBJECTIVE

List the six principles of learning and describe the function of each.

INTRODUCTION

Learning is an active process that takes place according to a number of well-defined principles. These principles are the will to learn, action, attention, organization, understanding, and review.

INFORMATION

THE LEARNING PROCESS

Will to Learn

The will to learn results from having a definite objective and recognizing the need to achieve that objective. A person is motivated to do a job when he knows exactly what he is expected to do and realizes why he must do it. Contrast the amount of knowledge that you got from the average high school lecture with the amount that you got from a briefing on an important job. You learned more from the job briefings chiefly because you were getting something that you were looking for and something that would affect your future well-being.

Action

We have said that learning is an active process. Your education, in the final analysis, depends entirely upon your participation in the learning situations which confront you. When you are faced with new ideas, facts, or principles, you are in a "learning situation;" and you learn as you react to and participate in that situation. Learning is in direct proportion to the amount of your reaction to a learning situation. Anything that you can do to generate definite mental action while listening or reading will help you to achieve effective learning.

Attention

The third principle in learning is attention, which means focusing the full power of your mind on the material that you wish to learn. When working with about 50 percent attention, you "take in" the material you hear or see; but it quickly fades from your mind and is never used. If your attention lies between the halfway mark and total attention, you will be able to understand and remember the material you see or hear. You should feel some interest or curiosity concerning the material presented. In your case, there should be little material in which you cannot develop a genuine interest if you honestly try to relate it to your present work or career.

Organization

You cannot learn a subject effectively simply by memorizing all the facts about it. Before you are able to use material that you have learned, you must understand its organization; that is, how the parts fit together to make a complete picture. If you can get the author's central idea and his general plan of attack, you will be able to follow more intelligently his individual ideas and items of information. If you know what the end result of your listening or reading will be, you can better interpret each detail.

Understanding

The fifth principle in learning is understanding. By this we mean getting the basic idea which the author is trying to get across. You can do this by putting the author's statement in your own words.

When you read material, you get the organization that the author considered most logical in dealing with his subject—you get his organization. In order to put the material to the best use, you must formulate in your mind the organization that makes most sense to you. This may or may not be the same as that used by the author.

Review

Few experiences are so vivid that we learn from them in one trial. Generally speaking, we must repeat any operation to make it our own. Material studied for an hour a day for four days, or even an hour a week for four weeks, will be remembered much better than material studied four hours one day and never reviewed. You will find in your own case that some review will give you better comprehension and better memory than study concentrated at one time with no review.

SUMMARY

We have said that learning does not take place in some mysterious and unexplainable fashion; neither is it a process that operates automatically when you are exposed to material to be learned. Learning is an active process that takes place according to a number of well-defined rules and principles. They are the will to learn, action, attention, organization, understanding, and review. All of these principles should be applied when forming good study habits.

LISTENING

OBJECTIVE

List three requirements for effective listening during a discussion or lecture.

INTRODUCTION

Listening is another important factor in the learning process. You must master the art of listening to get the most from a discussion or lecture. Proper listening will affect your studying, too. You must learn to ignore distractions in order to pick out the important points being presented. The six factors covered in Practice Lesson #2, "Principles of Learning," also apply to effective listening techniques.

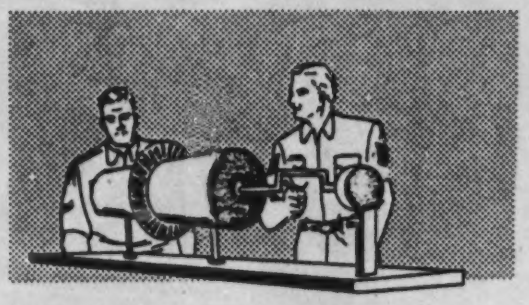


Figure 13. Learn to Listen and Listen to Learn

INFORMATION

You must have the *will to learn* in order to listen effectively. You will not pay close attention to a speaker unless you are interested in what he is saying.

Action is how you react to what the speaker says. You cannot sit with your body and mind relaxed and expect the speaker's points to impress themselves on your brain. It's like putting your car in neutral—you won't get very far.

To listen effectively and with understanding, you must give your undivided *attention* to the speaker. You cannot learn and retain the subject matter if you permit your mind to wander.

Organization is important to effective listening. You should be constantly alert to the speaker's organization of the subject. The subject organization should help you to *understand* the material. Without understanding, you will not learn or retain the subject matter.

Review is the last factor in listening to learn. To review a lecture, refer to your notes or a prepared outline. How well you take notes during the lecture has a definite effect on how effective your review will be. In most cases, it is wise to expand your notes as soon as possible after the lecture.

154

List the six factors that affect listening effectiveness.

1.
2.
3.
4.
5.
6.

||||||||||||||||||||

1. Will to learn
2. Action
3. Attention
4. Understanding
5. Organization
6. Review

Select the true statements:

a. By concentrating, you can reject sounds not related to the subject.

b. Review does not affect learning by listening.

c. You must respond mentally to listen effectively.

||||||||||||||||||||

a and c

Without mental response, you are not _____ to the speaker.

||||||||||||||||||||

listening

If you do not give your _____ to the speaker you cannot learn and retain the subject matter.

||||||||||||||||||||

attention

The subject _____ will aid you to _____ the material.

organization understand

To listen effectively you must:

a. Start listening when the instructor starts talking.

b. Keep listening until he stops talking.

c. Respond mentally to what he says.

NOTE TAKING

OBJECTIVES

1. List three rules for taking notes during a discussion or lecture.
2. Write an acceptable outline for taking notes during a discussion or lecture.

INTRODUCTION

The best way to review subject matter presented in a discussion or lecture is to refer to your notes. If your notes are to be useful, you must follow proven rules of note-taking.

INFORMATION

There are many rules which can be applied to note-taking but we'll confine this coverage to four basic ones. These rules are:

1. Listen for the speaker's main ideas and then write them down in your own words.
2. Be brief.
3. Record information—don't just list topics.
4. Organize your notes in the prescribed outline form.

Listen for the main ideas of the speaker. When you identify these ideas, write them down in your own words. Then as the discussion or lecture continues, jot down important facts which support each main idea.

Figure 14. Take Good Notes

Select the correct statement.

a. Only those items the speaker writes on the chalkboard are main ideas.

b. Good notes require writing down the main ideas in your own words.

c. The instructor will tell you when he is giving a main idea.

||||||||||||||||||||

b

A rule for good note-taking is "Be Brief." Don't try to write down everything the speaker says but don't just list topics either. Remember, your notes must make sense to you an hour, a day, or a week later. Plan to jot down only the key points and supporting facts.

Select the true statements.

a. A single word is usually sufficient notes on a single main idea.

b. You should rephrase and write down everything the speaker says.

c. Listing topics is an effective way to take notes.

d. Good notes must be as brief as clarity permits.

Figure 15. Pick Out the Key Points

IIIIIIIIIIIIIIIIIII

d

Another note-taking rule to follow is "take down information, not just topics." For example, if one of the topics covered in a lecture was "Safety" and your notes consisted of just that one word, you might have trouble recalling what was covered if you waited a week to review your notes. However, if you made the following notes, you would have an advantage:

1. Safety
   a. Driving
      (1) Obey laws
      (2) Don't drink and drive
      (3) Watch other driver
   b. Swimming
      (1) Swim with buddy
      (2) Know the water
      (3) Don't horseplay

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Which of the following is *not* a good rule for taking notes?

a. Be brief.

b. Write down information, not just topics.

c. Write down main ideas in your own words.

d. Use the speaker's exact words when taking notes.

||||||||||||||||||||

d

Some people write down useful information but due to a lack of organization, the information loses some of its effectiveness. Develop the habit of taking notes in outline form and they will be more useful to you. The Air Force approved outline format is shown below. Note that no capital letters or Roman numerals are used. Your notes should follow this outline.

1.

a.

b.

(1)

(2)

(a)

(b)

1

2

a

b

2.

a.

(1)

(2)

b.

You'll notice that I used this format in the sample outline of notes on page 35.

In the outline the key points are identified by the _____.

||||||||||||||||||||

numbers 1, 2, 3, etc.

Main subpoints are identified by _____. 159

IIIIIIIIIIIIIIIIIIII

letters a, b, c, etc.

During a lecture an instructor said that weapons of the US included the A-7, the RF-4, the C-141, and the C-5A aircraft, the Minuteman and the Titan Intercontinental Ballistic Missiles (ICBM), and the Sparrow and the Sidewinder Air Intercept Missiles (AIM).

Outline this information in the recommended Air Force outline format.

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Outline:

1. Aircraft
   a. A-7
   b. RF-4
   c. C-141
   d. C-5A
2. Missiles
   a. ICBM
      (1) Minuteman
      (2) Titan
   b. AIM
      (1) Sparrow
      (2) Sidewinder

As soon as possible after class, organize your notes and write in the supporting information that you didn't have time for during class. This will help you review for a test at a later date.

You should _____ and _____ notes taken in class as soon as possible after class.

organize supplement

When taking notes, write as legibly as possible. Don't be one who "can't read his own writing after it gets cold."

The four rules for note-taking are:

a. Listen for the speaker's main ideas and then write them down in your own words.

b. Be brief.

c. Record information—don't just list topics.

d. Organize your notes in the prescribed outline form.

NOTE: Obtain a dictionary for use with pages 39 through 42. If a dictionary is not available turn to page 43.

USING THE DICTIONARY

161

OBJECTIVES

1. Locate specific words in a dictionary, write or state their meaning and pronounce them correctly.
2. Alphabetize a group of words.

INTRODUCTION

A foreign student once said, "I have difficulty with the Engl:sh language. You have a 'patient' in the hospital, and you are 'patient' with your students." Here the same word is used two times with different meanings. Foreign students are not the only ones who have difficulty with our language. The above illustrates the need of having a knowledge of word meanings and how these meanings are influenced by other words in the sentence.

INFORMATION

One way to increase your knowledge of word meanings is to use the dictionary. Writers often use uncommon words. Anytime you read to learn you should have a dictionary near and you should use it.

To get the most from your studies, you should use a _____ to look up unfamiliar _____.

||||||||||||||||||||

dictionary words

You can build your vocabulary by using the dictionary but this alone isn't enough. You also must learn the vocabulary of your career field.

Every activity has its own _____ whether it is in the field of education, electronics, photography, or baseball.

||||||||||||||||||||

vocabulary

162

There are instructions and aids given in the dictionary to assist you in using it. A pronunciation key, usually located on the inside covers or bottom of each page, gives assistance in sounding the letters in words. In addition to the _____ key, detailed instructions in pronouncing words are given in the section in the dictionary titled "A Guide to Pronunciation."

||||||||||||||||||||

pronunciation

Many words have more than one definition given in the dictionary. The first _____ is the earliest acceptable meaning and those following it are usually given in order of the date of their acceptance.

||||||||||||||||||||

definition

Learn to open your dictionary to a page that is near the place where the word you are looking for is located. The guide words at the top of each page are very helpful. The first _____ _____ is the first word on the page.

||||||||||||||||||||

guide word

The second guide word is the last word on the page. If the word you are looking for is alphabetically between these two _____ _____ you will know it is on that page.

||||||||||||||||||||

guide words

Look up the word "alphabet" in your dictionary. Note that this word is divided into three syllables. In pronouncing this word the stress or accent, identified by the heavy stress mark, is on the first syllable. Look at some other words in the dictionary, and you will find some of them have two _____ _____; a heavy one and a lighter one.

||||||||||||||||||||

stress marks

The heavy stress mark is called the *primary accent* and the lighter stress mark is called the *secondary accent*. In pronouncing these words more _____ is given to the _____ with the heavy stress mark.

||||||||||||||||||||

stress syllable

Immediately following each word is a respelling of it to help you in its correct pronunciation. In this _____ the vowels are marked to show how they are sounded. Note these markings in the word "alphabet."

||||||||||||||||||||

respelling

These markings are called diacritical marks. The key to these sounds is at the bottom of the page or in the section "Guide to Pronunciation," near the front of the _____.

||||||||||||||||||||

dictionary

The letter or letters following the respelling of the word identifies its part of speech such as a noun, verb, adjective, etc. The letter "n" following the word "alphabet" identifies it as a _____.

||||||||||||||||||||

noun

The information enclosed within the brackets gives the origin or derivation of the word. Note that the word "alphabet" is _____ from the Latin word *alphabetum*, which in turn comes from the Greek words *alpha* and *beta*.

||||||||||||||||||||

derived or originated

The definition of the word is next. If there are several _____, you must consider the word in relation to its use in the sentence and then select the correct _____.

||||||||||||||||||||

definitions definition

164

A dictionary should be an important part of your study references. The more you use it the easier it will be to locate words and their meanings. Arrange the following words in alphabetical order and look up the definition of the words in italics.

lady, *ember*, stream, argue, profile *magnolia*, simple, ladies, *embarrass*, *beast*, argument, arguing

argue, arguing, argument, beast, embarrass, ember, ladies, lady, magnolia, profile, simple, stream

beast; 1a: an animal as distinguished from a plant b: a lower animal as distinguished from man c: a 4-footed mammal as distinguished from man, lower vertebrates, and invertebrates d: an animal under human control 2: a contemptible person

embarrass; 1a: to hamper the movement of b: HINDER, IMPEDE. 2a: to place in doubt, perplexity, or difficulties b: to involve in financial difficulties c: to cause to experience in state of self-conscious distress. 3: to make intricate: COMPLICATE.

ember; 1: a glowing fragment (as of coal) from a fire; esp: such a fragment smoldering in ashes. 2 pl: the smoldering remains of a fire.

magnolia; any of a genus (magnolia of the family Magnoliaceae, the Magnolia Family) of No. American and Asian shrubs and trees with entire evergreen or deciduous leaves and usu. showy white, yellow, rose, or purple flowers appearing in early spring.

TABLE OF CONTENTS

OBJECTIVE

Given a Table of Contents and a list of subjects, write page number of each subject.

INTRODUCTION

Knowing how to study is essential to your learning efforts. Since most students have a limited time for study, maximum use of this time is important. This section deals with the Table of Contents. Learning to use the Table of Contents will save you valuable minutes.

INFORMATION

The design of the Table of Contents varies with the author. The examples used in this text will familiarize you with some of the designs.

The Table of Contents on page 45 uses chapters and sections. If you are looking for information concerning crystals, you would locate this information in chapter 1, section B, page 6.

If you need information about stabilizing circuits which use diodes, you would locate this in chapter _____, section _____, page _____.

3 C 39

You are a technician who needs to review information about phase inverters. From the Table of Contents on page 45, you would find this material in chapter _____, section _____, page _____.

4 C 57

Another Table of Contents is shown on page 46. This one uses chapters, headings, and subheadings. You locate desired information in this Table of Contents in basically the same manner as the first example.

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You are going to write training literature and need information about the standards for illustrations. Where in the book would this information begin?

Chapter: _____, Title: _____

Heading: _____

Subheading: _____

Page: _____

||||||||||||||||||||

Chapter: 1, Preparing Training Literature
Heading: Quality Standards
Subheading: Illustrating
Page: 1-13

You want to find information about the use of study guides? Use the Table of Contents on page 46.

Chapter: _____, Title: _____

Heading: _____

Page: _____

||||||||||||||||||||

Chapter: 2, Study Guides
Heading: Purpose and Use
Page: 2-1

Go back to page 3 and briefly glance over the material. Don't forget the recite and review steps of the SQ3R planned method of study. Use them with this text, too.

DO NOT PLAN TO...CO

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HANDOUT
3ABR42331-HO-101
3AAR42371-HO-102

SB

Technical Training

Aircraft Environmental Systems Mechanic
Aircraft Environmental Systems Technician

GLOSSARY OF TERMS

28 September 1976

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
3370th Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE
DO NOT USE ON THE JOB

This handout is in three sections. Section I is a list of frequently used abbreviations. Section II is intended to give you general definitions that apply to several areas of study. Section III (electrical terms) is more specific in that the terms apply to one main area of study. Anytime you are studying a piece of material that has words of which you are not sure of the definition use this handout. If the definition is not in this handout please consult your instructor.

SECTION I. FREQUENTLY USED ABBREVIATIONS

ACFT--------Aircraft

A/C---------Air Conditioning

ATM---------Air Turbine Motor

Btu---------British Thermal Unit

CB----------Fire Extinguishing Agent (Bromochloromethane)

C/B---------Circuit Breaker

C-----------Celsius (previously Centigrade)

CFM---------Cubic Feet Per Minute

Cu.In.------Cubic Inches

ΔP----------Delta Pressure (Differential Pressure)

EBA---------Engine Bleed Air

F-----------Fahrenheit

GPM---------Gallons per minute

H_2O---------Water

Hg----------Mercury

LPM---------Liters per minute

PPM---------Pounds per minute

PHE---------Primary Heat Exchanger

psi---------Pounds Per Square Inch

psia--------Pounds Per Square Inch Absolute

psid--------Pounds Per Square Inch Differential

psig--------Pounds Per Square Inch Gauge

rpm-----------Revolutions Per Minute

SHE-----------Secondary Heat Exchange

SOV-----------Shut off Valve

σ-------------Sigma

SECTION II. DEFINITIONS OF GENERAL TERMS

-A-

ABORT	1-Of airborne persons or aircraft; to turn back from an aerial mission before completion, especially for reasons other than enemy action. 2-To cause an air mission, sortie, or operation to fall short of success for reasons other than enemy action.
ABSOLUTE TEMPERATURE	A temperature expressed in terms of a scale beginning at absolute zero.
ABSOLUTE ZERO	The temperature at which all thermal motion or heat action ceases. On the Fahrenheit scale it is equal to 459.7 degrees below zero. On the Celsius scale it is equal to 273.16 degrees below zero.
ACCELERATION	The action or process of velocity increase; the rate of velocity increase, often measured in G's.
ACCESSORY DRIVE	A special driveshaft and gears, operated off the engine, to actuate and drive accessories.
ACTUATE	To put into use; to move; to cause to operate.
ADIABATIC	The change in the temperature of the air or other gas due to a change in pressure on the air or gas.
AERODYNAMIC BREAKING FAN	A fan designed to create a drag on the turbine of some aircraft starters, thereby limiting the turbine speed.
AERODYNAMIC HEATING	The heating of an aircraft due to the friction of air, significant chiefly at high speeds.
AIR	The mixture of gases in the atmosphere. The element through which aircraft fly.
AIR CONDITION	The process of conditioning air. This is done by heating, cooling, cleaning the air, and controlling moisture content.
AIR FLOW	A flow or movement of air.
AIR INLET	An entrance for air.
AIR INTAKE	A scoop, duct, or the like for taking in air; an air inlet.
AIR PRESSURE	Either the static or dynamic pressure of air or both.
AIR SCOOP	A device or part mounted on the aircraft which opens toward the front for taking in air during flight.

AIR SEAL	Any partition, gasket, or the like used to block off or stop the flow or passage of air.
AIR START	An act or instance of starting an airplane's engine while in flight.
ALTIMETER	A flight instrument that indicates altitude above a given reference level, as above the sea or ground.
ALTITUDE	The elevation of an object above a given level, as above sea or ground. The vertical distance between any point in the atmosphere or air and a reference point on the earth's surface.
ALTITUDE INDICATOR	Any device for indicating altitude.
AMBIENT	Surrounding, encompassing, as in ambient air, ambient temperature.
ANEROID	A disc shaped metallic capsule from which all air has been evacuated, which expresses its sensitivity to changes in atmospheric pressure by expanding and contracting.
ANOXIA	Literally the absence of oxygen in the blood cells, or tissues, as would be the case if a person were at 50,000 feet without benefit of oxygen equipment.
ANTI (prefix)	Counter; against; opposing.
ANTI-G DEVICE	Any device designed to protect a person against high G forces.
ANTI-G SUIT	A suit designed to protect a person against positive G forces over 1.75 G.
ANTI-ICER	A device designed to prevent the formation of ice.
ANTI-ICING	Of a compound, a fluid or equipment that prevents icing.
ANTI-ICE SCREEN	A wire mesh screen located in the turbine outlet of some air conditioning systems that is designed to prevent icing of the water separator.
ATMOSPHERE	1-The body of air which surrounds the earth. 2-The pressure of the air at sea level, equal to 14.7 psi.
ATMOSPHERIC PRESSURE	The static force or pressure exerted by the atmosphere in any direction in any part of the atmosphere envelope.
AUTOMATIC TEMPERATURE CONTROL	Designating mechanisms that work in reaction to certain conditions to automatically control the temperature of an aircraft cockpit or cabin.

AUXILIARY	Of air operated systems; that supplements or is in addition to regular air operated systems, as in rain removal systems, anti-G suit systems, canopy seal systems, and windshield defogging and anti-icing systems.
AUXILIARY POWER UNIT	A power unit that can be used in addition to, or in place of other sources of power.
AXIAL FLOW	In a jet aircraft, the flow of air along the longitudinal axis of the engine.

-B-

BAILOUT	The action of bailing out of an aircraft by parachuting.
BAILOUT OXYGEN BOTTLE	A portable metal bottle containing oxygen to be used by a person after bailout at high altitudes. Sometimes called a "bailout oxygen cylinder."
BALL BEARING	A bearing in which the moving parts operate against freely revolving steel balls contained in a race, chiefly for the purpose of reducing friction; anyone of the balls in such a bearing.
BAROMETER	An instrument for measuring atmospheric pressure, used in such instruments as an altimeter.
BAROMETRIC PRESSURE	Atmospheric pressure as measured by a barometer.
BAROMETRIC SWITCH	A switch activated by an aneroid reacting to a barometric pressure.
BELLOWS	An open, flexible container operated by atmospheric pressure.
BENCH CHECK	A work shop check of the condition, completeness, or working order of a piece of equipment.
BENDS	A painful cramping in the joints caused by a rapid rise to high altitudes without the use of oxygen.
BERNOULI'S LAW	A law of physics stating that as the velocity of a fluid increases, its internal pressure decreases.
BLEED	To drain or divert all or part of the contents of an air line or chamber.
BLOWER	A device for moving large volumes of air at low pressures.
BONDING	A system of connections or contacts which insure that the metal parts of an aircraft form a continuous electrical unit thus preventing the arcing of static electricity.

BOUNDARY LAYER	A thin layer of air next to an air foil, distinguishable from the main air flow by distinctive flow characteristics of its own set up by friction.
BOUNDARY LAYER CONTROL	The design or control of airfoils and certain airfoil attachments to reduce or remove undesirable aerodynamic effects as parasite drag, caused by the boundary layer; the science of such design and control.
BOURDON TUBE	A metallic C-shaped or coil shaped tube open at one end to receive gas or fluid pressures, used in certain instruments as a pressure measuring device.
BREATHER TUBE	A tube providing an opening in the sump of an ATM, a starter, or a turbine assembly to equalize the pressure in the oil sump with atmospheric pressure.
BREECH	The container on a cartridge starter where the cartridge of ammonium nitrate is placed, for igniting.
BRITISH THERMAL UNIT	A unit of heat. The heat required to raise the temperature of one pound of water, at its maximum density, one degree Fahrenheit. Also, the heat to be removed in cooling one pound of water one degree Fahrenheit.
BUCKET	One of the blades or vanes attached to a turbine wheel.
BULKHEAD	A partition or frame serving to divide, support or give shape to the fuselage of an airplane.
BURNER CAN	A combustion chamber in a jet engine or combustion heater.
BY-PASS	1-A path for current or fluid to be carried around something. 2-A route used as an alternate when some obstruction makes use of the normal route impracticable.

-C-

CABIN	An inclosed compartment in an aircraft for passengers or crew members. Also known as cockpit.
CABIN HEATER DUCT	A duct for conveying heater air to an aircraft cabin.
CABIN LEAKAGE TESTER	Used to supply air to the aircraft cabin for testing the cabin for air tightness under pressurized conditions.
CABIN PRESSURE	The air pressure in an aircraft cabin.
CAM	A part mounted on a shaft and used to impart a reciprocating or alternating motion to another part by bearing against it as it rotates.

CAM FOLLOWER	A part that rides the cam.
CANOPY	Any overhanging cover as in "a canopy of an aircraft."
CANOPY SEAL	Used to seal the cabin to an airtight condition. Usually inflated by air pressure.
CAPSULE	An air tight ejectable airplane cockpit or cabin.
CARBON DIOXIDE SYSTEM	A system using carbon dioxide for extinguishing fire in an aircraft.
CARTRIDGE	A solid propellant of ammonium nitrate used to turn the turbine of a cartridge-pneumatic starter.
CARTRIDGE-PNEUMATIC STARTER	Used to start aircraft engines by use of either a solid propellant cartridge or bleed air.
CASTELLATED NUT	A nut divided into slots to receive a cotter pin and thus resembling a castle.
CELLULOSE NITRATE	Any of several esters of nitric acid used as an explosive. Produced by treating cotton or some other form of cellulose with a mixture of nitric and sulphuric acids. Used in explosives such as in a fixed fire extinguisher squib. Also called "gun cotton."
CELSIUS	A thermometer scale (sometimes called Centigrade) in which 0 degrees represents the freezing point and 100 degrees represents the boiling point of water under standard atmospheric conditions.
CENTRIFUGAL	Moving or directed away from the center of rotation.
CHANGE OF STATE	A change in the physical characteristics of a substance such as when water becomes steam or steam becomes water.
CHECK POINT	A known or designated point used as a reference in troubleshooting an electrical system.
CHECK VALVE	A valve that automatically prevents a reverse flow of a gas or fluid.
CLEAR ICE	A transparent ice deposited in layers on the airfoils of an airplane in flight. Also called glaze.
CLIMB	Of an airplace; to ascend or gain altitude especially under power.
CO_2	Fire extinguisher agent.
COCKPIT	See Cabin

COMBUSTION	A chemical action, or burning; in a combustion heater the burning of a fuel-air mixture.
COMBUSTION CHAMBER	A chamber or cylinder-like assembly where fuel and air are mixed, ignited, and burned.
COMPENSATOR	Any device used to offset or allow for undesirable forces or motions.
COMPONENT	A constituent part of a whole, especially one having no function apart from the whole, as the wing of an airplane.
COMPRESSOR	A machine or apparatus for compressing something; especially for compressing air.
CONDENSE	To change state from a gas to a liquid.
CONDENSER	A device for removing heat from a gas for the purpose of causing the gas to condense to a liquid.
CONDUCTION	Heat transmission by contact of two substances.
CONSTANT FLOW OXYGEN EQUIPMENT	A kind of oxygen equipment designed to supply a continuous flow of oxygen to the user. Also called continuous flow oxygen equipment.
CONTINUOUS PRESSURE BREATHING	A kind of pressure breathing in which a minimum amount of pressure variation exists inside the mask. See pressure breathing.
CONTROL AIR	Compressed air used as a controlling device.
CONTROL PANEL	A surface or panel on which switches, rheostats, and indicators are located for controlling and supervising system operation.
CONTROL SURFACE	In a broad sense, any movable airfoil used to guide or control an aircraft including the rudder, elevators, ailerons, spoiler flaps, trim tabs, and the like.
CONVECTION	The vertical movement of a limited body of air. The rising of relatively warm, light air; the downward movement of relatively cold, heavy air.
CONVERTER	As applied to an oxygen system. A double walled, vacuum insulated container that is spherical in shape and is used as a storage space for liquid oxygen.
COOLER	Heat exchanger that cools substances flowing through it.
COOLANT	Any substance used to cool.

CORROSION	To eat away gradually by chemical action. Also called rust.
COWLING	A covering of metal or other material placed over or around an aircraft component or section for directing and regulating the flow of cooling air; for streamlining and for protecting the part or section covered.
CUT OFF SPEED	The speed at which electrical power to the starter control valve is removed, thereby closing the starter control valve and stopping the rotation of the pneumatic starter.

-D-

DECELERATION	The action or process of velocity decrease; the rate of velocity decrease, often measured in G's.
DECOMPRESSION	The process of decreasing the air pressure within a chamber or cabin.
DEICER	Any of several devices used especially during flight for keeping certain surfaces of an aircraft free of ice.
DEICER BOOT	A rubber strip on the leading edge of an airfoil actuated pneumatically to break the ice that has formed.
DEMAND REGULATOR	A device used in an aircraft oxygen system to supply oxygen automatically through the mask to a flyer according to the demand, the flow being controlled according to altitude.
DENSITY	The weight per unit volume of a substance.
DEPRESSURIZE	To release the pressure from a pressurized compartment of an aircraft.
DESICCANT	A chemical which absorbs moisture from the air. Used to keep the air inside packing cases or pieces of equipment dry.
DESICCATOR	A unit containing a chemical which absorbs moisture from the air.
DIAPHRAGM	A dividing partition, membrane, or capsule that expands, contracts, or vibrates, serving various purposes in certain airplane parts.
DIFFERENTIAL PRESSURE	The difference between two pressures.

DIFFERENTIAL RANGE	Applicable to aircraft pressurization; a range of altitudes where a preset differential pressure will be maintained between the inside and outside of the aircraft cabin.
DOUBLE HINGED SWINGING GATE DUCT SUPPORT BRACKET	A duct support bracket found in the leading edge of wing that will allow a pivot action to take place during expansion and contraction of the duct.
DUCT	A tube or passage for conveying air or gases to its point of use.
DUCT UNIVERSAL JOINT	A bellows type assembly placed in the duct runs to provide for absorption of movement in the ducts due to thermal stresses and structure leading.
DUMP VALVE	Applicable to aircraft pressurization; a valve used during emergencies (bailout) for rapid decompression of the pressurized areas.

-E-

ELEVATOR	A control surface, usually attached to the horizontal stabilizer, moved to make the tail of the aircraft go up and down.
ENGINE BLEED AIR	Compressed air that is bled from a jet engine or gas turbine unit.
ENGINE NACELLE	A nacelle primarily used for housing an engine and its associated parts.

-F-

FAHRENHEIT	A temperature scale in which 32 degrees is the freezing point and 212 degrees represents the boiling point of water under standard atmospheric conditions.
FAN	A device for moving large volumes of air at extremely low pressures.
FEEDBACK	In electronics and electricity, feedback is the transfer of energy from the output to the input of the same electrical system.
FILTER	Any device or substance through which something is passed in order to cleanse, purify, or separate it.
FIRE EXTINGUISHER	A device used in putting out fires. May be a fixed or portable unit.
FLAMMABLE	Combustible, easily ignited.

FLAP	Any control surface such as speed brakes, dive brakes, or dive recovery brakes, that are used primarily to increase the lift or drag on an airplane.
FLOWMETER	An instrument that measures and displays the rate of a large flow of a liquid or gas.
FLOWRATOR	An instrument that measures and displays the rate of a small flow of a liquid or gas.
FOLDING WING	A wing so hinged that it may be turned upward.
FORCE	Power or energy exerted against a material body in a given direction.
FRANGIBLE DISC	A device usually made of metal which is scored to break at the score lines. Used in fire extinguisher systems.
FREEZING POINT	The temperature at which substances become stiff or immobile.
FROST	A feathery deposit of minute ice crystals or grains upon a surface or object formed directly from vapor in the air.
FUSELAGE	The main structure or central section of an airplane which houses or contains the crew, passengers, or cargo.
FUSIBLE PLUG	A safety device having an insert of a low melting point alloy. At excessive temperatures the alloy will melt and release the substance inside.
FUEL NOZZLE	Atomizes and sprays the fuel into the combustion chamber of a heater for proper burning.
FUEL PUMP	Delivers aircraft fuel under pressure to the fuel nozzles in the combustion heaters.

-G-

G-FORCE	The gravitational force or pull of the earth.
GAS	Any substance, like air, carbon dioxide, or chlorine that has no shape or volume independent of a container that might hold it, and tending to expand indefinitely. Distinguished from a liquid or a solid.
GAS TURBINE	A mechanical unit that spins or rotates in reaction to a flow of gas passing through or over it.

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GAS TURBINE COMPRESSOR	A small gas turbine engine that is mounted on board the aircraft to provide hot, high-pressure air for ground checking of the air conditioning systems and starting aircraft engines.
GAS TURBINE UNIT	A small gas turbine engine that supplies hot, high-pressure air for aircraft use and emergency electrical and hydraulic power. This unit will be mounted on-board the aircraft.
GASKET	A piece or ring of rubber, metal, paper, etc., placed around a piston or joint to make it leak proof.
GAUGE	A measuring instrument. Also spelled gage.
GO-NO-GO GAUGE	A key like piece of metal used for measuring clearances between points.
GRAVITY	1-The force that makes a body, if free to move, accelerate toward the center of the earth. 2-A G-force due to acceleration and deceleration.
GROUND AIRCART	A device consisting of a small gas turbine engine used to provide hot, high-pressure air for starting the aircraft engines and ground checking the air conditioning system.
GROUND CHECK	To check or inspect an airplane or piece of equipment on the ground before it becomes airborne.
GROUND COOLING EJECTOR	Forces engine bleed air out of a nozzle to create a low pressure area in the heat exchanger ram air exhaust, that draws cooling ram air across the heat exchanger. See jet pump.
GROUND SUPPORT EQUIPMENT	The equipment required to maintain and care for an aircraft while on the ground.
G-SUIT	A garment containing a number of bladders for covering parts of the body below the chest, designed to inflate automatically to the exact pressure to prevent or retard the pooling of blood below the heart during exposure to abnormal G forces. Also called anti-blackout suit and anti-G suit.

-H-

HEAT EXCHANGER	1-In aircraft air conditioning, a device or system whereby heat is transferred from the hot engine bleed air to the ram air, thereby cooling the engine bleed air. 2-In a more general sense, any device such as a water radiator.

HANG FIRE	Pertaining to cartridge starters; an abnormal delay between the actuation of the ignitor and the establishment of the balanced burning pressure of the cartridge during a cartridge start.
HIGH PRESSURE OXYGEN EQUIPMENT	A kind of aircraft oxygen equipment designed to withstand a relatively high internal gas pressure.
HIT KIT SPOT WELDER	A portable welding machine that can be used to repair metal foil duct insulation.
HORIZONTAL STABILIZER	The horizontal component of an airplane's empennage extending on both sides of the fuselage.
HYPEROXIA	Excess of oxygen in the body.
HYPERVENTILATION	Over breathing; excessive loss of carbon dioxide from the blood.
HYPOXIA	Oxygen deficiency in the blood, cells or tissues.

-I-

ICING	The act or process of atmospheric moisture freezing upon the surfaces of an aircraft; the condition in which this phenomenon takes place.
IGNITER PLUG	A spark plug used to ignite the fuel mixture in a combustion heater.
IGNITION HARNESS	A system or assembly of wires, together with any shielding or conduits inclosing them, for conducting electric current to the igniter plug of a combustion heater.
IGNITION SYSTEM	The electrical system which supplies the spark for the combustion of fuel in a combustion heater.
INCONEL	(A trademark name) A nickel, chrome, and iron alloy designed for corrosion resistance at fairly high temperature.
INDICATOR	An instrument or device.
INDICATOR, RATE OF CHANGE	Indicates the rate of pressure change in the cabin or cockpit of an aircraft.
INNER LINER	The inner shell of a combustion chamber inserted to diffuse the compressed air in the chamber and maintain an efficient flame pattern.
ISOBARIC PRESSURE	Having the same barometric pressure.

ISOBARIC RANGE	Applicable to aircraft pressurization; a range of altitudes where the atmospheric pressure in the cockpit is held at the same pressure regardless of the aircraft altitude.
	-J-
JET PUMP	A device that will create a low pressure area in the ram air outlet of a heat exchanger which will draw additional ram air across the heat exchanger. See ground cooling ejector.
JET NOZZLE	A nozzle producing a jet of liquid or gas. An exhaust nozzle for the escape of gases.
	-K-
KINETIC	Pertaining to or due to motion.
	-L-
LABYRINTH SEAL	A carbon seal used in refrigeration packs of aircraft air conditioning systems.
LAMINATED METAL	Metal consisting of two or more metal plates bonded securely together.
LANDING FLAP	A flap used especially to slow an airplane down for landing.
LAW OF HEAT TRANSFER	Heat always travels from hot to cold.
LEAK TEST	Tests made in various manners to determine the existence and location of leaks.
LEAK TEC	A soapy solution used to determine the existence and location of leaks in an oxygen system.
LIMIT SWITCH	On valves; a switch that is actuated when the open or closed limits of a valve are reached.
LIQUID	A substance, like water, neither solid nor gaseous, that flows freely and conforms to the shape of a container.
LITER	A liquid measure. Approximately 34 ounces.
LOW PRESSURE OXYGEN EQUIPMENT	A kind of aircraft oxygen equipment designed to function at a relatively low internal gas pressure.
LUBE	Short for lubricating oil.
	-M-
MANOMETER	Used to measure absolute and differential pressures.

MASTER SWITCH	The main switch that will control the starting and stopping of the entire system.
MATTER	Anything that has weight and occupies space.
MERCURY BAROMETER	A barometer using mercury as the sensitive element for measuring atmospheric pressure.
METAL FOIL INSULATION	An insulation wrapped around hot air ducts to minimize the heat loss from the ducts, prevent damage to the structure and equipment adjacent to the ducts, and prevent injury to personnel coming in contact with the ducts.
MINIMUM TEMPERATURE CONTROL SYSTEM	An aircraft temperature control system designed to prevent the temperature of the refrigerated air from getting too low.
MISFIRE	Pertaining to the cartridge starter, the failure of the cartridge of a cartridge starter to ignite.
MICRON	Measurement of size used in rating filters.
MODULATING VALVE	A valve that, as part of a cabin temperature control systems, varies its position to maintain the temperature at a constant point.
MOISTURE SEPARATOR	A device used to remove moisture from an aircraft air conditioning system.

-N-

NACELLE	A separate streamlined inclosure on an airplane for sheltering and housing something.
NEGATIVE G	A G-force exerted upon the human body acting from the foot to head.
NOMENCLATURE	A set of systems of names or symbols given to items of supply and equipment, or to other variously identifiable thing as a means of classification and identification.
NOZZLE	A duct through which a liquid or gas is directed, designed to increase the velocity of the liquid or gas.
NULL	A condition existing when a minimum unbalance signal is received from a bridge circuit. The bridge circuit is at balance.
NULL INDICATOR	A center scale ammeter connected across a bridge circuit and used to indicate whether the bridge circuit is at balance.

-O-

O-RING SEAL	A synthetic rubber seal made in the shape of the letter O that is used to prevent leaks.
OIL COOLER	A kind of a radiator in the lubrication system of an aircraft for cooling the lubricating oil.
OIL DIPSTICK	A dipstick for measuring oil in tanks or similar containers.
OIL FILTER	A device used to remove foreign matter from the oil before it reaches the areas to be lubricated.
OIL LEVEL	The level in a unit or component at which oil must be carried for proper lubrication.
OPEN WORK ORDER	A work order or job that has not been completed.
ORIFICE	An opening; mouth or outlet of a tube, cavity vent. A calibrated circular hole used to regulate flow.
OUTSIDE AIR TEMPERATURE	The temperature directly outside the aircraft (ambient).
OVERRUNNING SPRAG CLUTCH	Part of an aircraft starter that transmits the torque of the turbine only in one direction, thereby preventing the aircraft engine from driving the starter after the engine starts.
OXYGEN	A chemical element, occurring free in the atmosphere as an odorless, colorless, tasteless gas and also in combination in other substances. It can be compressed to a liquid state.
OXYGEN BOTTLE	A metal bottle designed to hold oxygen for breathing at high altitudes.
OXYGEN LACK	A condition of scarcity or absence of oxygen in the atmosphere, as at high altitudes, or in a confined space unsupplied by oxygen.
OXYGEN MASK	A mask that covers the mouth, nose, and lower face, used in inhaling oxygen from a tank or bottle.
OXYGEN STATION	A place or point in an aircraft where an oxygen mask can be attached to the oxygen supply system.
OXYGEN TENSION	The faculty of oxygen at a given pressure and a given amount to extend itself into the cells of lungs or into the blood or tissues of the body.

-P-

PACK PRESSURE LIMITER	A pneumatically actuated type unit designed to regulate the airflow giong to the air conditioning system.
PERIODIC DOCK	A dock for the periodic inspection or overhaul of an aircraft or engine.
PERIODIC INSPECTION	An inspection repeated either at regular intervals of calendar time or in reference to certain equipment after it has been used for a given number of times.
PHILLIPS SCREW	A holding screw having a special head with two slots which cross one another and are deeper at the center than at the ends.
PHILLIPS SCREWDRIVER	A cross tipped screwdriver; to be used with a Phillips head screw.
PISTON ENGINE	A reciprocating engine, especially an internal-combustion reciprocating engine.
PITOT-STATIC TUBE	A tube arrangement, which, when inserted into a moving air steam measures impact pressures and static pressures.
PLENUM CHAMBER	An air chamber opening into the compressor chamber on certain turbojet or turboprop engines where air is collected for the compressor.
PNEUDRAULIC	Of or pertaining to mechanisms or devices that work by both pneumatic and hydraulic action.
PNEUMATIC	1-Mechanisms, devices, or tools worked by compressed air or other gases. 2-Also used to designate associated devices as in pneumatic compressor.
POSITIVE G	A G-force exerted upon the human body acting from the head to the feet.
PRECOOLER	A device used to initially cool the engine bleed air.
PREFLIGHT INSPECTION	1-A regular procedure followed by a ground crew each time or each day before a particular aircraft is flown. 2-A regular part of the periodic inspection made before the aircraft is given a flight test.
PREHEATER	A device for warming up something before use.
PRESSURE	Amount of force distributed over each unit of area. Expressed in pounds per square inch (psi).
PRESSURE, ABSOLUTE	Pressure measured in reference to zero pressure.

PRESSURE, ATMOSPHERIC	The pressure exerted by the earth's atmosphere. Under standard conditions, at sea level, atmospheric pressure is 14.7 psia or 0 psig.
PRESSURE ALTIMETER	An altimeter that measures and indicates altitude by means of differences in atmospheric pressure.
RESSURE ALTITUDE	1-A simulated pressure altitude in a low pressure chamber. 2-either indicated pressure altitude or calibrated pressure altitude.
RESSURE BREATHING	The breathing of oxygen or other suitable gases through a special system or apparatus at a pressure in excess of the ambient pressure.
PRESSURE CABIN	A pressurized cabin.
PRESSURE DEMAND OXYGEN EQUIPMENT	A kind of low pressure oxygen equipment that functions either as demand oxygen equipment or as continuous pressure breathing.
PRESSURE GAUGE	A gauge or instrument that measures pressure, or is actuated by pressure.
RESSURE RATIO	A ratio between two pressures as the ratio between the inlet and outlet pressures of a compressor.
PRESSURE REGULATORS	Devices which establish the working pressures in a system and maintains them at that point.
PRESSURE SUIT	A garment designed to provide pressure upon the body so that the respiratory and circulatory functions may continue normally.
PRESSURE SWITCH	1-Composed of a sealed case with an air inlet connection, diaphragm assembly, and double set of electrical contacts. Air pressure against the diaphragm operates the electrical contacts. 2-A switch activated by a given ambient pressure.
PRESSURE, TEMPERATURE, & VOLUME RELATIONSHIP	As pressure increases, temperature increases and volume decreases.
PRESSURIZATION	The term used to designate the pressurizing of aircraft cabins to a lower altitude.
PRESSURIZE	To produce and maintain in a cockpit, cabin or compartment of an aircraft an air pressure higher than the ambient atmospheric pressure, in order to compensate for the lowered pressures at high altitudes.
PUMP, OIL	Supplies pressurized oil for lubrication purposes.

PYROMETER	Precision measuring instrument for temperature indications.

-Q-

QUADRICYCLE LANDING GEAR	A landing gear consisting of four separate wheel units.
QUICK DISCONNECT FITTING	A pipe or electrical fitting in an aircraft designed for ready disconnection and connection.

-R-

RADIAL FLOW COMPRESSOR	A centrifugal compressor in which air is drawn into a rotating impeller axially, being discharged radially at the circumference of the impeller at high velocity into a diffuser, where velocity is reduced resulting in conversion of kinetic energy into pressure energy.
RADIATION	1-The act or process of radiating or the state of being radiated; also, that which is radiated. 2-The combined process of emission, transmission, and absorption of radiant energy.
RAM	The forward motion of an air scoop or air inlet through the air.
RAM AIR SCOOP	A scoop extended into the air stream to provide an emergency source of ram air for ventilation of the crew compartment of the airplane.
RANKINE SCALE	A temperature scale that uses Fahrenheit degrees, but makes the 0 degree signify absolute zero (degrees R). The freezing point of water on the Rankine Scale is 491.69°.
REDUCTION GEAR	A gear assembly between a powered shaft and another shaft, by which the latter shaft is driven at a lower rpm than the powered shaft.
REED AND PRINCE SCREWDRIVER	A trade name for a kind of screwdriver having a blunt tip and a cross shaped cross section at the top.
REGULATION	The act of governing, controlling, or directing; or the state of being controlled or directed.
REGULATOR	A device that regulates the flow or pressure of a liquid gas.
REGULATOR, CABIN PRESSURE	A device that controls cabin pressure by controlling the amount of pressurized air leaving the cabin.
REGULATOR, CANOPY SEAL	A device that regulates air pressure for pressurizing the canopy seal.

REGULATOR, AIR PRESSURE	A device that establishes the working pressure of an air operated system and holds it at that point.
REGULATOR, CABIN TEMPERATURE	A device operated either electrically, electronically, or pneumatically provided to maintain cabin temperature at a predetermined setting.
RELIEF VALVE	A safety valve used to relieve excessive pressure.
RUPTURE DISC	A metal disc installed in an air conditioning, fire extinguishing, or oxygen system that will burst when pressure becomes too high.

-S-

SEAL	A device to prevent leakage of liquid, gas, or air.
SEALANT	A sealing compound.
SEAT, VALVE	That part of a component which forms the seal between the housing and the valve when the valve is in the closed position.
SIGHT GAUGE	Used to observe the condition of a fluid in a system or component.
SOLENOID	A coil of insulated wire wound in the form of a spring or on a spool. A solenoid uses DC or AC for its operation.
SOLENOID VALVE	A valve actuated by a solenoid.
SPRING LOADED	Held or driven under spring pressure.
SQUIB	1-Any of various small size explosive devices. 2-Specifically an electrically detonated explosive charge in a thin walled metal container.
STATIC AIR PRESSURE	Static pressure exerted by air upon an object especially by the air of the atmosphere as in a pitot-static tube.
STATOR	In machinery, a part that remains fixed in relation to a rotating part.
STATOR BLADE	A blade or vane that remains fixed with respect to a rotating blade.
STRUT, ENGINE	Any rigid structure that protrudes from a wing, fuselage, or other surface of an aircraft to support an engine.
SUBASSEMBLY	A unit or element of a major assembly, consisting of two or more separate parts assembled together.

SUMP	A reservoir at a low point in a fuel or lubrication system where the liquid is collected and stored.
SWINGING GATE DUCT SUPPORT BRACKETS	Brackets mounted in the leading edge of the wings to allow a pivot action to take place during expansion and contraction of the ducts.
SWITCH, DIFFERENTIAL PRESSURE	An electrical switch actuated by differential pressure.
SWITCH, PRESSURE	An electrical switch that is opened or closed when a specified pressure is applied to it.
SWITCH, THERMAL	An electrical switch made of bimetallic contacts that will open or close in response to the temperature it senses.

-T-

TACHOMETER	An instrument that indicates in revolutions per minute the rotational speed of a unit.
TECHNICAL ORDER	An AF publication that gives specific technical directions and information with respect to inspection, storage, operation, modification, and maintenance of given AF equipment.
TECHNICAL ORDER KIT	A kit consisting of the tools or parts necessary to use or maintain a piece of equipment as prescribed in an AF TO.
TEMPERATURE	Degree of hotness or coldness measured on a definite scale.
TEMPERATURE, AMBIENT	The temperature of the air surrounding the object under consideration.
TEMPERATURE SELECTOR	A device used by the crew members to select the temperature to be maintained in the cockpit or cabin.
TEMPERATURE SENSING ELEMENT	A temperature sensitive resistance that is part of the balance bridge circuit and senses the temperature changes that take place in the cabin or the duct.
TEST SET	A set of equipment used to test system operation and locate faults and troubles in the systems maintained by this career field.
TEST STAND	A strong stationary stand on which the component part of the systems found in this career field are tested for operation.
THERMAL COMPENSATOR	A device installed in the ducts of the bleed air system to allow for linear growth of the duct caused by thermal expansion of the duct.

THERMISTOR	A small resistor in which the resistance varies over a wide range with temperature.
THERMOCOUPLE	A connection or junction of two pieces of dissimilar metals which produces a current when heated.
THERMOSTAT, MERCURY	An apparatus consisting of a glass tube and metal contacts in which mercury rises and falls as it expands or contracts from changes in temperature. This unit is used to regulate temperature in an aircraft cabin.
TOLERANCE COMPENSATOR	A device installed in ducts in the bleed air system to improve the necessary adjustments in duct lengths due to duct and aircraft tolerances.
TORQUE	A movement that produces or tends to produce rotation, twisting, or torsion.
TORQUE WRENCH	A wrench designed to disengage when the torque required to turn a bolt or nut increase beyond a certain point.
TRICYCLE LANDING GEAR	A three wheel landing gear in which no tail wheel or tail skid is used, normally consisting of two main wheels with an auxiliary wheel forward.
TURBINE	A mechanical device that spins in reaction to an airflow passing over or across the vanes.
TURBINE COMPRESSOR	A combination of a turbine wheel and a compressor wheel mounted on the same shaft. The compressor is used to raise the temperature and pressure of the air passing through it and put a load on the turbine to keep it from overspeeding. The turbine cools the air applied to it by rapid expansion and by converting heat energy to mechanical energy. This unit is the cooling unit found in some aircraft air conditioning systems.
TURBINE AND FAN ASSEMBLY	An expansion type cooling unit used in some aircraft air conditioning systems. The fan is used to put a load on the turbine and draw ram air across a heat exchanger. The turbine cools the air applied to it by rapid expansion and by converting heat energy to mechanical energy.
TURBINE WHEEL	A wheel or disc equipped with blades or vanes designed to spin in reaction to an air flow passing over or across the vanes.
TURBOJET ENGINE	A type of jet engine that uses a gas turbine to drive an air compressor and engine accessories.
TURBOPROP ENGINE	A turbojet engine designed to drive a propeller by transmitting power through a shaft.

-U-

UNPRESSURIZED RANGE	Applicable to aircraft pressurization, the range of altitudes where both the aircraft altitude and cabin altitude are equal.

-V-

VACUUM	A reduction of pressure below atmospheric pressure; usually stated in inches of mercury.
VACUUM PUMP	A pump for exhausting a system. A pump designed to produce a vacuum in a closed system or vessel.
VALVE	Any device such as a swirling plate, hinged lid, plug, or ball through which the flow of gas or liquid may be checked, stopped, started, or regulated.
VALVE, AIR CONDITION SYSTEM SHUT OFF	A device used to stop and start the flow of engine bleed air to the air conditioning system.
VALVE, ANTI-G SUIT	A device that regulates the pressure going to the anti-G suit and stops and starts the air flow going to the suit.
VALVE, BLEED AIR PRESS. REGULATOR & SHUT OFF	A device that starts and stops the flow of engine bleed air going to the air conditioning system and regulates the pressure.
VALVE, BUTTERFLY	Usually a round type valve with an upper and lower bearing.
VALVE, BYPASS	A passage for air to go around a unit.
VALVE, CO_2 DIRECTIONAL	Used on aircraft fire extinguisher installations to direct the CO_2 to the desired engine.
VALVE, CO_2 TRIGGER RELEASE	Used on portable CO_2 fire extinguishers to start and stop flow of CO_2 at will.
VALVE, CO_2 QUICK RELEASE DISCHARGE	Used on CO_2 fire extinguishers to release the CO_2; this valve, once opened, will be held open constantly and cannot be shut off.
VALVE, FLOW CONTROL & SHUTOFF	A device used on some aircraft air conditioning systems that operates as both a shut off valve and an air flow control valve.
VALVE, RAM AIR	Allows air to enter the cabin directly from the outside.
VALVE, SAFETY RELIEF	A valve designed to relieve the pressure from a vessel or system whenever the pressure exceeds the setting of the valve.

VALVE, SLIDING GATE	Used in low pressure systems; consists of a piece of metal that slides to open or close the opening in the duct or valve.
VALVE, SPOON	Usually a round valve with 2 upper bearings and no lower bearing.
VALVE, WATER SEPARATOR BYPASS	A pneumatically operated valve that opens when the water separator becomes plugged or frozen to allow conditioned air to bypass the separator and enter the cockpit area.
VALVE, VACUUM RELIEF	Applicable to aircraft pressurization; a valve that prevents outside atmospheric pressure from exceeding inside the cabin pressure. Valve will open to allow high outside pressure to equalize the pressure inside.
VAPOR	Any substance in its gaseous state.
VAPORIZE	1-To convert something into a gaseous state, as through spraying or heating a liquid. 2-Of a liquid to go into a gaseous state.
VARIABLE AREA NOZZLE	A nozzle the opening of which is a variable size.
VELOCITY	1-Speed. 2-Speed or rate of motion in a given direction and in a given frame of reference.
VENTILATION	The process of moving air through the cabin area.
VENTURI	1-A venturi tube. 2-A device used to control the flow of air in an air conditioning system.
VENTURI TUBE	A short tube with a constricted throat which, when placed in a fluid flow parallel to the flow, brings about an increase in flow velocity at the throat with a consequent reduced pressure within the fluid at the throat.
VOLATILE	Easily passing away by evaporation.
VOLATILITY	The quality or property of a liquid for evaporating.
VOLUME	Amount of space included by the bounding surface of an object.

-W-

WALK AROUND OXYGEN BOTTLE	A carry around oxygen bottle.
WARNING LIGHTS	A system of lights that illuminate to give the pilot warning of a malfunctioning system.

WATER BOILER	A type of heat exchanger that uses water as the cooling agent; heat energy is transferred from the engine bleed air to the water causing the water to boil and evaporate.
WATER SEPARATOR	A device in an aircraft air conditioning system designed to remove the water condensed in the air as a result of refrigeration.
WICK	Pertaining to a turbine used for cooling; allows oil to flow to the blanket by absorption.
WING ROOT	The very base of an airplanes wing, where it joins and is faired into the fuselage.

SECTION III. ELECTRICAL TERMS DEFINITIONS

-A-

A-C Generator	Rotating electrical machine, generally known as an alternator that converts mechanical power into alternating current.
Adjustable Resistor	Resistor whose resistance can be changed mechanically.
Admittance (Y)	The measure of the ease with which an alternating current flows in a circuit.
Air Gap	The space between any two iron or steel elements in a magnetic circuit.
Alnico	An alloy of iron with aluminum, nickel and cobalt having magnetic properties such that it can be used to produce an extremely strong magnet with relatively small mass.
Alternating Current (AC)	Current periodically changing direction and constantly changing magnitude.
Alternation	A term used to signify that part of the change in an alternating current during which it rises from zero to maximum and back to zero again. Half of one complete cycle.
Alternator	An alternating current generator.
Alternator, Three-Phase	Produces 3 voltages 120° apart.
Ammeter	An instrument for measuring current, with a scale graduated to read directly in amperes.
Ampere (Amp, IA)	A practical unit of current. The amount of current flowing through one ohm resistance at the pressure of one volt.
Ampere-Hour (AH)	A current of one ampere flowing for one hour. Term used in rating storage batteries.
Ampere-Hour Capacity	The amount of current a battery can provide for one hour. Theoretically, a battery rated at 100 ampere-hours will furnish 100 amperes for 1 hour, or 50 amperes for 2 hours, or 5 amperes for 20 hours.
Ampere-Turn	The magnetizing force produced by one ampere of current flowing through one turn of a coil in an electromagnet.
Amplification	A process whereby a small fluctuating signal voltage or current is stepped up to a value many times greater than its original strength.

Amplification Factor (u)	A vacuum tube rating indicating the maximum increase in signal strength which can be provided by a given tube. It is the ratio of a small plate voltage change to a small grid voltage change which would produce the same change in plate current.
Amplifier	A device used to increase the signal voltage, current or power. It is generally composed of a vacuum tube and associated circuits called a stage. It may contain several stages in order to obtain a desired gain.
Amplitude	The maximum value of the displacement from the zero position.
Angle	The space between intersection lines; the ratio between the arc and the radius of the arc.
Anode	A positive electrode, such as the plate of the vacuum tube.
Apparent Power (AP)	The product of source voltage and source current in an alternating current circuit. Expressed in volt-amperes.
Armature	As applied to: Motors or DC Generators - It refers to the movable or rotating part, consisting essentially of coils of wire around an iron core. Alternators - The circuit which contains the conductors that have the EMF induced in them and that are in series with the load. Relays - The moving portion of a magnetic circuit.
Arc	A discharge of electricity through a gas.
Armature Core	Assembly of laminations forming the magnetic circuit of the armature.
Armature Reaction	Reaction between the magnetic flux of the armature and that of the main magnetic field.
Atom	One of the minute particles of which the universe is composed; a natural group of electrons, protons and neutrons.
Attraction	The force that tends to make two objects approach each other. Attraction exists between two unlike magnetic poles and between two unlike static charges.
Automatic Circuit Breaker	Device that automatically opens a circuit, usually through electromagnetic means, when the circuit exceeds a safe value.

Autotransformer	A transformer having one continuous winding. A part of this winding is used for both the primary and secondary coil.
Average Value	That value obtained by adding unit values and dividing the sum by the number of units. The average value for half a cycle of AC is .636 times the maximum or peak value.

-B-

Back Electromotive Force	The counter EMF of any system is the effective EMF within the system which opposes the passage of current in a specified direction.
Ballast Resistance	A steadying resistance used to limit variations of current in a circuit.
Barrier Layer	Surface of contact between a metal and semiconductor. It acts as a rectifier of alternating currents.
Battery	A device for converting chemical energy into electrical energy.
Bias	A fixed voltage, usually negative, applied to the grid of a vacuum tube so that it operates along a certain portion of its characteristic curve.
Bias Resistor	A resistor, placed in grid, cathode or plate circuit, which supplies a grid bias proportional to current passing through it.
Bimetallic	Always made up of two unlike metals.
Bleeder	A resistance connected in parallel with a power-supply output to protect equipment from excessive voltages if the load is removed or reduced; to improve the voltage regulation and to drain the charge remaining in the filter capacitors when the unit is turned off.
B-power Supply	Power source which supplies positive voltage for other electrical devices.
Bonding	Connecting the metal parts of the aircraft with flexible conductors, so that all parts will have the same voltage or potential.
Breadboard	In electronics, an arrangement in which components are fastened temporarily to a board or chassis for experimental purposes.
Breakdown Voltage	1. Voltage at which an insulator or dielectric ruptures. 2. Of a semiconductor diode, the voltage measured at a specified current in the breakdown region.

Bridge Circuit — A network in which the output indicating device or the load is bridged across intermediate points of the two parallel elements across which the input voltage is applied.

Bridge Rectifier — Full-wave rectifier with four elements connected in a bridge so that direct voltage is obtained from one pair of opposite junctions when alternating voltage is applied to the other pair.

Brush — A metal or carbon block used to make contact with a rotating or other moving part in an electrical circuit.

Bus Bar — Heavy metal bars used to carry current. The wires of several circuits may be connected to one bus bar or one terminal.

-C-

Calibration — Process of comparing an instrument or device with a standard to determine its accuracy or to devise a corrected scale.

Capacitance (C) — That property of a system of conductors and dielectrics which permit the storage of electrical energy in an electrostatic field between the conductors; unit of measurement is the Farad.

Capacitive Reactance (X_c) — The opposition which a condenser offers to AC or pulsating DC. It is expressed in ohms.

Capacitor — A system consisting of two conductors of considerable surface separated by a comparatively thin dielectric, thus possessing an appreciable capacitance. An electrical device or unit designed especially to have the quality of capacitance (condenser).

Capacity — See capacitance.

Cathode (K) — Negative, or the electron emitting electrode of a vacuum tube.

Cell — A single unit capable of serving as a DC voltage source; also a single rectifier unit.

Dry Cell - Composed of an outer shell of zinc, an electrolyte of paste and a carbon rod in the center.

Primary Cell - Commonly called "dry cell," a battery that cannot be recharged due to a nonreversible chemical reaction that takes place between the plates and the electrolyte when the cell is in use.

	Secondary Cell - A battery cell that can be recharged by reversing the current flow through the battery.
	Wet Cell - A case containing lead coated plates and a liquid electrolyte.
Characteristic	A distinguishing trait, quality or property.
Charge	The act of supplying electrical energy to a metal object, a condenser or a storage battery. When an object has more electrons than normal, it has a negative charge. When it has less electrons than normal the object has a positive charge.
Charged Bodies	Bodies with an excess or deficiency of electrons.
Choke Coil	A coil used to impede the flow of pulsating current or alternating current by means of its self-inductance.
Circuit	A closed path usually including a source of voltage.
Circuit Breaker	An automatic switch which opens a circuit under abnormal conditions such as an overload. It also may be "tripped" or opened by hand.
Circuit Diagram	Schematic drawing of the electrical connections of a device.
Coil	A number of turns of wire wound on an iron core or a number of turns of wire wound on a form of insulating material.
Coil, Toroidal	A coil wound in the shape of a doughnut.
Cold Cathode	A type of cathode which does not require heat to emit electrons.
Collector	In a transistor, an electrode through which a primary flow of carriers leaves the interelectrode region.
Collector Junction	In a transistor, a junction normally biased in the high resistance direction, through which the current can be controlled by the introduction of minority carriers.
Collector Rings	"Sliprings" - a contact ring for making connection through brushes between a winding on a rotating part of a machine or apparatus and an external circuit.
Commutation	The process of converting alternating current which flows in the armature of a DC generator to DC.

Commutator	A drum built up of insulated segments connected to the armature winding of a generator or motor to or from which current is taken by the brushes.
Commutator Ripple	Small periodic variations in voltage and current output of a DC generator caused by passage of brushes over individual commutator segments.
Component	A functional part of a subsystem or electrical circuit which is essential to the operational completeness of the subsystem of circuit.
Condenser	See capacitor.
Conductance (G)	The ease with which a conductor passes current. The reciprocal of resistance. Expressed in ohms.
Conductor	Any material which possesses an appreciable proportion of free electrons and therefore permits a current to pass.
Contact	Part of an equipment designed to touch a similar part to permit current to flow, or designed to break this union to cause current to cease.
Contactor	A device for repeatedly establishing and interrupting an electric circuit.
Continuity	The property of having a complete or continuous electrical path.
Control Grid (G)	The electrode of a vacuum tube, other than a diode, upon which the signal voltage is impressed in order to control the plate current.
Control Panel	A panel, open or closed, where switches, rheostats, meters, etc., are installed for controlling and protecting electrical machinery.
Copper-oxide Rectifier	A metallic rectifier made of alternate layers of one or more discs of copper on copper-oxide.
Core	Magnetic material placed within a coil to increase the magnetic intensity of the magnetic field. Magnetic material inside a relay or inductor coil winding.
Coulomb (Q)	A quantity of electricity; the number of electrons passing a point, in a given conductor when one ampere flows for one second.
Counter Electromotive Force	A voltage (CEMF) induced in a coil or conductor of opposite direction to the applied voltage.

Current (I)	Movement of electrons as measured in amperes.
Current Limiter	An electrical device used to limit the current flow in a circuit.
Cycle (~ or c)	One complete set of recurring events which takes place periodically.

-D-

D'Arsonval Movement	The mechanism of a permanent-magnet-moving coil instrument.
D-C Generator	(See Direct Current Generator).
D-C Resistance	Opposition to the flow of direct current offered by a circuit or body.
Deenergize	To stop the flow of current in a circuit, or remove the voltage in a circuit, as by opening a switch.
Delta	Method of connecting the stator windings in a 3 Ø motor or generator.
Density	Concentration of anything; quantity per unit volume.
Depletion Layer	In a semiconductor, a region in which the mobile carrier charge density is insufficient to neutralize the net fixed charge density of donors and acceptors.
Dielectric	A nonconducting material.
Dielectric Constant	A numeral which describes the effectiveness of a dielectric. It compares the capacity of a condenser using dielectric with that of an otherwise identical condenser using air as a dielectric. Air has a dielectric constant of one.
Diode Tube	A two-element tube having cathode and plate. Used mostly as a rectifier. A diode allows electrons to pass in only one direction, from cathode to plate.
Direct Current (DC)	Current which is constant in direction. Pulsating DC - Current which varies or fluctuates in value, but flows in only one direction.
Direct Current Generator	Rotating electrical machine which converts mechanical power into D-C power.
Discharge	1. Release of stored up energy. 2. In a storage battery, the conversion of the chemical energy of the battery into electrical energy.

Dropping Resistor	Resistor used to decrease a given voltage to a lower value.

-E-

Effective Current	That value of alternating current which will cause the same effect as a given value of direct current. It is equal to .707 times maximum or peak value.
Effective Value (RMS)	The value of AC which has the same effect as the corresponding value of DC. For a sine curve the effective value is .707 times the maximum value.
Effective Voltage	That value of alternating voltage which will cause the same effect as a given value of DC voltage. It is equal to .707 times maximum or peak value.
Electrical Charge	The quantity of electricity on (or in) a body is the excess of one kind of electricity over the other kind. A plus sign (+) indicates that the positive is in excess, a negative sign (-) indicates that the negative is in excess.
Electrical Degrees	A measurement of time in an electrical cycle. One degree = 1/360 of a cycle. At 60-cycle frequency, 1 degree = 1/21, 600th of a second. The actual length of time represented by the amount of electricity produced and shown in electrical degrees with respect to mechanical degrees and time.
Electricity	A form of energy due to the separation and independent movement of certain parts of atoms called electrons.
Electrode	A solid conductor by which a current passes to or from a liquid or gas to another solid conductor of different material.
Electrolyte	The liquid or chemical paste which is used between the plates in a battery or dry cell.
Electrolytic Capacitor	Capacitor which is comprised of two plates separated by an electrolyte. Under the action of the applied DC voltage, a film of hydrogen gas is formed on one plate, and it is this film which is the electrolyte. This type of construction makes it possible to concentrate large values of capacitance in relatively small space.
Electromagnet	A magnet produced by the flow of an electric current through an associated coil.
Electromagnetic Field	Field of influence which an electric current produces around the conductor through which it flows. Magnetic field resulting from the flow of electricity.

Electromagnetic Induction	Production of a voltage in a coil due to a change in the number of magnetic lines of force passing through the coil.
Electromotive Force (emf)	That force which tends to cause an electric current or electron flow by producing a difference of potential.
Electron	The elementary charge of negative electricity.
Electron Drift	Actual movement of electrons in a definite direction through a conductor during current flow, as contrasted from transfer of energy from one electron to another by collision.
Electron Emission	The liberation of electrons. As from the cathode of a vacuum tube.
Electron Theory	The theory which explains all electrical phenomena by the independent movement of electrons.
Electrostatic	Pertaining to electricity at rest, such as charges on an object.
Electrostatic Charge	Electric charge stored on a capacitor or on an insulated body.
Electrostatic Field	Field of force between two electrically charged bodies.
Element	1. Substance, in chemistry, that cannot be divided into simpler substances by any means ordinarily available. 2. Of a semiconductor device, any integral part of the semiconductor device that contributes to its operation.
Emitter	In a transistor, a region from which charge carriers that are minority carriers in the base are injected into the base.
Emitter Junction	In a transistor, a junction normally biased in the low-resistance direction to inject minority carriers into the base.
Energy	The capacity for performing work. Energy of motion is kinetic energy. Energy of a stationery or static form is called potential energy. Energy cannot be created or destroyed but may change its form.
Energize	Supply power necessary to provide normal and effective operation.
Excess Electron	An electron introduced into a semiconductor by a donor impurity and available to promote conduction. An excess electron is not required to complete the bond structure of the semiconductor.

Excitation	Excitation of an alternator is the resultant of the magnetic lines from the exciting source and magnetic lines of force set up by the load current through the armature.
Exciter	A direct current generator supplying current for excitation of one or more other machines.
External Resistance	Resistance that is connected externally between the terminals of a battery or other power source.

-F-

Farad (f)	The unit of electrostatic capacity. A condenser possessing the capacity of one farad will allow one coulomb of electrons to flow upon its plates when the potential of one volt is applied for one second.
Field (Electric or Magnetic)	A term used to indicate a region where magnetic or electrostatic forces are exerted.
Field Coil	A suitable insulated winding to be mounted on a field pole to magnetize it.
Field, Differential	Field which has the series and shunt coils connected to oppose each other.
Field Distortion	Undesired shift in the fields between the N and S pole due to CEMF in the armature windings.
Field of Force	Term used to describe to total force exerted by an action-at-a-distance phenomenon such as gravity upon matter, electric charges acting upon electric charges, magnetic forces acting upon other magnetics or magnetic materials.
Field Pole	Magnetic material on which field coils may be mounted.
Field Windings	The coil of an electromagnet used to supply the magnetic field in motors and generators.
Filament	The wire through which current is sent in a vacuum tube or a light bulb to utilize the heat given off due to the current flow.
Filter	Any system of inductance, capacitance and resistance which is used to smooth the pulsations of DC from a rectifier or commutator.
Fixed Bias or Grid Bias	A bias voltage of constant value, such as one obtained from a battery, or other DC power supply.
Fixed Capacitor	Capacitor having definite capacitance value that cannot be adjusted.

Fixed Resistor	Resistor having a definite resistance that cannot be adjusted.
Flow	Passage of electrons (a current) through a conductor or through space between electrodes.
Fluorescence	Light given off as a result of electron bombardment.
Flux (ϕ)	A general term used to designate collectively all the electric or magnetic lines of force in a region.
Flux Density	The number of lines of force per unit area.
Force (F)	That which tends to change the state of rest or motion of matter.
Forward Current	Current which flows upon application of a forward voltage.
Forward Direction	In a semiconductor diode, the direction of lower resistance to the flow of steady direct current.
Free Electrons	Electrons which are not bound to a particular atom, and are free to move under the influence of an electric field.
Frequency (f)	The number of complete cycles which an alternating EMF or current executes in one second. Generally, the number of recurring events in a given period of time.
Frequency - = $\frac{\text{\# of poles}}{2}$	X $\frac{\text{RPM}}{60}$
Frequency Meter	A meter used to indicate the number of cycles per second of an alternating current.
Full-Wave Rectifier	Rectifier arranged so that current is allowed to pass in the same direction to the load circuit during each half cycle of the alternating current supply.
Fuse	A wire strip or bar of metal designed to melt or to interrupt the circuit when a predetermined current is exceeded.

-G-

Gain	Ratio of output to input voltage, current, or power, usually expressed in decibels.
Galvanometer	A D'Arsonval-type meter used for measuring or indicating extremely small electric currents. Its scale usually indicates relative deflection, and the actual current, voltage or charge value must be calculated.

Generator	A machine for the conversion of mechanical energy into electrical energy.
Graph	Pictorial presentation of the relation between two or more variable quantities, such as between an applied voltage and the current it produces in a circuit.
Grid	A tube element in the form of a metallic mesh or screen through which electrons pass under control of a potential applied to the grid.
Grid Bias	See fixed bias.
Grid Current	The current passing to or from a grid through the space inside a vacuum tube; measured in the input circuit.
Ground	A connection, intentional or accidental, between an electrical circuit and the earth, some conducting body, or chassis serving in place of the earth.
Ground Potential	Zero potential with respect to ground or earth.
Grounded	Connected to earth or to some conducting body which serves as earth.
Growler	Test equipment used to check motors and generators for opens, shorts and grounds.

-H-

Half-Wave Rectifier	A nonlinear device used to rectify alternating current into direct current. Only one-half of the input cycle is rectified, the output being a pulsating direct current.
Heat Sink	A device for the absorption or transfer of heat away from a critical part or parts.
Heater (H)	An electric heating element for supplying heat to an indirectly heated cathode.
Henry (h)	The unit of inductance. A circuit has an inductance of one henry when the current, changing at the rate of one ampere per second, induces one volt CEMF.
Hertz (Hz)	A unit of frequency equal to one cycle per second.
Hole	A mobile vacancy in the electronic valence structure of a semiconductor which acts as a positive charge with a positive mass.
Hole Current	The current in a semiconductor associated with apparent positive charges designated as holes.

Horizontal	Perpendicular to the direction of gravity. In the direction of, or parallel to, the horizon. On a level.
Horsepower (hp)	A unit of electrical power equivalent to the amount of power in a mechanical horsepower. Electrically, one horsepower equals 746 watts.
Horseshoe Magnet	Permanent magnet or electromagnet bent in the shape of a horseshoe or having a U shape so as to bring the pole together.
Hot	Connected, alive, energized; pertains to terminal or any ungrounded conductor. Not grounded.
Hydrometer	An instrument used to determine the specific gravity of the liquid of a storage battery; hence, the state of charge of the batte
Hypotenuse	The side opposite the 90° angle of a right triangle.
Hysteresis	Magnetic hysteresis occurs when a magnetic substance is subjected to a varying magnetic field and is due to intermolecular friction which is a form of power loss in electromagnets in the form of heat, generally a lag. Dielectrics are also subjected to a varying electric field causing heat in the dielectric.
Hysteresis Loss	Power loss in an iron core transformer or other alternating current device due to a magnetic hysteresis.

-I-

Impedance (Z)	The total opposition, measured in ohms, offered to passage of alternating current by the resultant of resistance and capacitive and inductive reactance.
Impurity	An atom in a crystal which is foreign to the crystal. An imperfection that is chemically foreign to the perfect crystal.
Impurity, Acceptor	In semiconductors, an impurity which may induce holes.
Impurity, Donor	In semiconductors, an impurity which may induce electronic conduction.
Induced	Produced as a result of exposure to the influence or variation of an electric or magnetic field.
Induced Current	Current due to an induced voltage.
Induced Electromotive Force	The electromotive force induced into a conductor due to the relative motion between the conductor and the magnetic field.

Inductance (L)	The physical property of a circuit which tends to oppose a change in current flow.
Induction	Magnetic Induction - When a material is placed in a magnetic field it has magnetism induced into it. Self-Induction - The production of a counter-electromotive force in a conductor when its own magnetic field collapses or expands with a change in current in the conductor. Mutual Induction - (Transformer Action) - As current is varied in a conductor, a second conductor parallel to the first will have an EMF induced into it. Note: The more nearly parallel, the greater the EMF induced. If the conductors are at right angles no voltage will be induced. Electromagnetic Induction - (Generator Action) - When a conductor and a magnetic field have relative motion, a voltage is induced into the conductor. A voltage is induced if either the conductor or the field is moved. The conductor must be moved other than parallel to the lines of force.
Induction Motor	AC motor-rotation achieved by reaction of main magnetic field and the magnetic field of the induced current in the rotor.
Inductive Circuit	Circuit containing a greater amount of inductive reactance than capacitive reactance.
Inductive Reactance (X_L)	The opposition to the flow of alternating or pulsating current caused by the inductance of a conductor. X_L is measured in ohms.
Inductor	A coil. A wire lying in an armature slot and forming part of a coil. That part of a wire which moves in a magnetic field and in which an electric current or pressure is induced. The careless practice of using the word conductor for inductor should be avoided.
In Phase	Describing a condition in which two or more fluctuating components such as an AC voltage and current attain maximum values simultaneously in the same direction.
Input	1. Current, voltage, power, or driving force applied to a circuit or device. 2. Terminals or other places where current, voltage, or power, or driving force can be applied to a circuit or device.

Input Transformer	Transformer used to transfer energy from a voltage source to the input of a circuit or device.
Instantaneous Value	The value of an alternating voltage or current at a given instant of time.
Insulated Wire	Conductor covered with a nonconductive material.
Insulation	A material which has a sufficiently high resistance to permit its use for separating one electrical circuit or wire from others.
Insulator	A medium which will not conduct electricity.
Intensity	Relative strength of electric or magnetic energy.
Interlock Switch	Safety switch which deenergizes voltage when doors, access covers or other openings are opened.
Internal Resistance	Resistance within a cell or battery to the flow of current.
Interpole	Placed between the main field poles of a DC motor or generator to reduce field distortion.
Inverter	A device which changes DC to AC. It consists of an AC generator driven by a DC motor.
Ion	A "charged" atom or molecule. One that has fewer or more electrons than normal.
Ionization	The process whereby a substance becomes ionized. Utilized in a gaseous tube to take advantage of the good current carrying characteristics of the ionized gas. Present when insulators break down.
Ionize	To make an atom lose an electron. The atom which loses the electron becomes a positive ion, the gaining atom is a negative ion.
IR Drop	Voltage drop produced across a resistance R by the flow of current I through the resistor.
I^2R Loss	Power loss in transformers, generators, connecting wires, and other parts of a circuit due to the flow of current through the resistance of the conductors.
Iron Core Coil	Coil in which iron forms part or all of the magnetic core, linking its windings.
Iron Loss	Power loss occurring in iron cores of electric machines, coils, transformers, etc., due to hysteresis and eddy currents.

-J-

Jack	A connecting device to which a wire or wires of a circuit may be connected.
Joule	A unit of energy of work. In electricity, one watt-second.

-K-

Kilo (K)	One thousand.
Kilovolt-Amperes (KVA)	Volt amperes divided by 1,000. One KVA equals 1,000 volt amperes.
Kilowatt (KW)	Watts divided by 1,000. One KW equals 1,000 watts.
Kilowatt-Hours (KWH)	A measure of the consumption of electrical energy. The unit of electrical energy equal to 1,000 watts being consumed for one hour.

-L-

Lag	Of two alternating electrical quantities of the same frequency the one that reaches a particular cyclic point later is said to lag the other. This lag is expressed in electrical degrees.
Lagging Current	Current flowing in a circuit which lags voltage applied to the circuit.
Laminated	Made of thin layers.
Laminated Core	The core of an armature, transformer, etc, built up of stamping of sheets of iron which are insulated from each other to reduce eddy currents.
Law of Charges	Like charges repel; unlike charges attract.
Law of Electromagnetic Induction	(Faraday's Law) Electromotive force induced in a circuit is proportional to the change of the flux of magnetic induction linked with the circuit. When the change in flux linkage is caused by motion, relative to a magnetic field, of a conductor forming a part of an electric circuit, the electromotive force induced in the circuit is proportional to the rate at which the conductor cuts the flux of magnetic induction.
Law of Electrostatic Charges (Coulombs Law)	Force of attraction or repulsion between two charged bodies concentrated at two points in an isotropic medium is proportional to the produce of their magnitudes and is inversely proportional to the square of the distance between them.

Law of Magnetism	Like poles repel; unlike poles attract.
Lead (Material)	A term given to a wire or conductor.
Lead (Theoretical)	Of two alternating electrical quantities of the same frequency, the one that reaches a particular cyclic point first is said to lead the other. This is expressed in electrical degrees.
Leading Current	Current that reaches its maximum value before the voltage that produces it.
Leakage	Term used to express current loss through imperfect insulators.
Left-Hand Rule	For generators, stretch the thumb and first finger of the left hand at right angles to each other in the same plane and the second finger at a ninety degree angle perpendicular to the plane of the thumb and first finger. For a conductor in a generator armature, when the thumb indicates the direction of magnetic lines of force the second finger indicates the direction of electron flow. For a motor the right hand rule is used. For a current carrying wire, if the fingers of the left hand are closed around the wire so that the thumb points in the direction of electron flow, the fingers will be pointing in the direction of the magnetic field.
Lenz's Law	Whenever an induced current is produced by any motion, current will flow in a direction such that mechanical forces will be produced which oppose the motion.
Linear	Applied to meter scales, having equal graduations.
Line Drop	Voltage drop existing between two points of a power line due to resistance.
Lines of Force	Imaginary lines to indicate the direction and intensity of a magnetic or electrostatic field.
Line Voltage	Voltage level of the main power supplied to equipment.
Load	1. Power consumed by a machine or circuit in performing its function. 2. Resistor or other impedance which can replace some circuit element temporarily or permanently removed. 3. Power that machine or apparatus will deliver. 4. Device used to absorb power and convert it into the desired useful form. 5. Impedance to which energy is being supplied. 6. Power consuming device connected to a circuit.

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Loss	Amount of electrical attenuation in a circuit, or the power consumed in a circuit component. 2. Energy dissipated in accomplishing useful work; usually expressed in units of watts.

-M-

Magnet	A magnetic material which has the property of attracting or repelling other magnetic substances.
Magnetic Amplifier	A device using one or more saturable reactors to control the field strength of a generator.
Magnetic Circuit	The complete path of magnetic lines of force.
Magnetic Field	Space in which magnetic lines of force exist.
Magnetic Flux	The total flow of magnetic lines of force through a magnetic circuit.
Magnetic Flux Density	Magnetic field intensity measured in oersted.
Magnetic Lines of Force	Imaginary lines used for convenience to designate the direction in which magnetic forces are acting as a result of a magnetomotive force.
Magnetic Pole	The part of the magnet where the lines of force enter or leave the iron and where the forces of attraction and repulsion are concentrated.
Magnetic Saturation	The point of magnetization in an electromagnet where an increase in current causes only a very small increase in magnetism.
Magnetic Shield	Sheet or core of iron, enclosing instruments to protect them from stray magnetic fields by providing a convenient path for the magnetic lines of force.
Magnetism	The property of the molecules of certain substances, as iron, by virtue of which they may store energy in the form of a field of force and is due to the motion of the electrons in the atoms of the substance; a manifestation of energy due to the motion of a dielectric field of force.
Magnetomotive Force	That force which produces magnetic flux; measured in ampere-turns.
Majority Carrier	In semiconductors, the type of carrier constituting more than half the total number of carriers. The majority carriers may be either holes or electrons, depending on the construction of the semiconductor.
Matter	Anything which has weight and occupies space.

Maximum Value	The greatest instantaneous value of an alternating current or voltage.
Maxwell	Centimeter-gram-second electromagnetic unit of magnetic flux. It is equal to one oersted per square centimeter, or to one magnetic line of force.
Meg or Mega	A prefix meaning one million times.
Megger	High range ohmmeter used for measuring insulation resistance values or other high resistances.
Megohm (MO)	A large unit of resistance; equal to one million ohms.
Mica	A mineral used for insulating purposes because of high dielectric strength and resistance to high temperatures.
Micro (μ)	A prefix meaning one-millionth of; designated by the Greek letter Mu.
Microfarad (μ f)	Practical unit of capacitance; one millionth of a farad.
Micro-Micro (μ μ)	One millionth of one millionth.
Milli	A prefix meaning one thousandth.
Milliammeter	A meter calibrated in milliamperes.
Milliampere (ma)	A unit of current equal to one-thousandth of an ampere.
Minority Carrier	In semiconductors the type of carrier constituting less than one half of the total number of carriers.
Molecule	The smallest particle of a substance which can exist and still retain all of the characteristics of that substance.
Molecular Theory of Magnetism	Assumption that each molecule of matter is a separate magnet and that in ferromagnetic materials these magnets all line up with their magnetic poles pointing in the same direction when the material is magnetized.
Motor	A machine which converts electrical energy into mechanical energy.
Motor Starter	A device for protecting electric motors from excessive current while they are reaching full speed.
Mu	Permeability, amplification factor, prefix micro.

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Mutual Induction	See induction (mutual).

-N-

Negative	A term used to describe a terminal or point that has more electrons than normal; such as the negative terminal of a battery.
Negative Bias	A bias placing a negative charge on some tube element in respect to another tube element. Usually making the control grid negative in respect to the cathode.
Negative Temperature Coefficient	Temperature coefficient expressing the amount of reduction in the value of a quantity, such as resistance per degree of increasing temperature.
Network	Special type of electric circuit which cannot be classified in terms of series and parallel parts.
Neutron	The small particle of an atom having no electric potential.
Nonlinear	In meters, a term used to express unequal graduations in the meter scale.
N-P-N Transistor	A transistor which consists of a thin slice of P-type semiconductor material sandwiched between two layers of N-type semiconductor.
N-P Semiconductor	See crystal diode.
Nucleus	Central part of the atom which makes up most of the weight of the atom. An atomic nucleus is made up of two kinds of fundamental particles, protons and neutrons. It has a positive charge equal to the number of protons it contains.

-O-

Ohm	The unit of electrical resistance. It is that value of electrical resistance through which a constant potential difference of 1 volt across the resistance will maintain a current flow of 1 ampere through the resistance.
Ohmic Value	Resistance in ohms.
Ohmmeter	An instrument used for measuring the resistance of a circuit.

Ohm's Law	The current in an electrical circuit is directly proportional to the electromotive force in the circuit. It is the fundamental law of electrical circuits and is true of all metallic circuits and most circuits containing an electrolyte resistance. The most common form of the law is E = IR, where E is the electromotive force, I is the current flow in the circuit, and R is the resistance of the circuit.
Ohmmeter Zero Adjustment	Potentiometer or other means provided to compensate for the reduction of battery voltage with age in an ohmmeter.
Open Circuit	1. Condition of an electrical circuit caused by the breaking of continuity of one or more of the conductors of the circuit; usually an undesired condition. 2. Circuit which does not provide a complete path for current to flow.
Oscilloscope	An instrument for showing, visually, graphical representations of waveforms encountered in electrical circuits.
Out-of-Phase	Having waveforms that are of the same shape but do not pass through corresponding values at the same instant.
Output	1. Current, voltage, power, or a driving force delivered by a circuit or device. 2. Terminals or other places where current, voltage, power, or other driving force may be delivered by a circuit or device.
Overload	Condition where the load is greater than the rated load of a device.
Overload Relay	A device which opens a circuit when the current exceeds a specified level.
Oxidation	The chemical process of combining with oxygen, often by exposure to air.

-P-

Parallel Circuit	An electrical circuit which has two or more paths for current to return to its source.
Parallel-Series	Circuit in which two or more parts are connected together in parallel to form parallel circuits and in which these circuits are then connected together in series so that both methods of connections appear.
Part	A mechanical unit which cannot readily be subdivided such as a tube, resistor.
Peak	Maximum instantaneous value of an alternating quantity.

Pentode	A five-element tube.
Period	Time required for the completion of one cycle.
Permanent Magnet	A magnet not dependent on a current for magnetization.
Permeability	The ability of a material to conduct magnetic lines of force, as compared to air.
Phase	The fraction of a cycle that has lapsed since a voltage or current has passed through a given cyclic point.
Phase Adapter	A device containing a coil and a capacitor for changing single-phase current into three-phase current.
Phase Difference	The relation between two sine wave quantities of the same frequency as to time that they pass a given cyclic point on their respective sine waves. The amount of time is expressed in electrical degrees.
Pi Network	Network of three impedances, two across the line and a third inserted in one line between the first two. Connected in such a manner as to resemble the Greek letter pi. π
Plate (P)	See anode.
Plate Voltage	The DC voltage applied between the plate and cathode of a vacuum tube.
P-N-P Transistor	A junction transistor formed by a slice of N-type semiconductor between two layers of P-type semiconductors.
Polarity	1. Condition of an electrical circuit by which the direction of current flow can be determined. Usually applied to batteries or other direct voltage sources. 2. Two opposite charges, one positive and one negative. 3. Quality of having two opposite magnetic poles, one North and one South.
Pole Piece	Piece of ferromagnetic material forming one end of a magnet and shaped so as to control the distribution of the magnetic flux in the adjacent medium.
Polyphase	Having more than one phase; as in three-phase.
Positive	A term used to describe a terminal having fewer electrons than another.
Positive Temperature Coefficient	Characteristic of a device or substance in which the resistance of a substance increases when the temperature increases.

Potential	Difference in voltage between two points of a circuit; frequently one is assumed to ground (zero potential). Generally expressed in volts.
Potential Barrier	Region in which the electric potential is such that moving electric charges attempting to pass through it encounter opposition and may be turned back.
Potential Difference	Algebraic difference between two points or individual potentials. Voltage existing between two points.
Potentiometer	A resistor which has a movable contact arm which can be set at any point of the resistor. The applied voltage is connected to the fixed end terminals of the resistor, and the output circuit is connected between the movable contact and one of the fixed terminals. Rotating the movable contact varies the proportion of the total voltage which is applied to the output circuit.
Power	Time rate of doing work or expending energy. In electrical systems, the basic unit is the watt.
Power Factor (PF)	The ratio expressed in percentage of actual power consumed in an AC circuit over apparent power.
Power Supply	Source of electrical energy required for normal operation of any electrical device or system.
Power Transformer	Transformer used to change the supply voltage to the various higher and lower values required for a system operation.
Primary	The first, in electrical order, of two or more coupled circuits, in which a change in current induces a voltage in the other or secondary circuit; such as the primary winding of a transformer. The primary is usually connected to the source of power.
Primary Current	Current flowing in the primary winding of a transformer.
Primary Voltage	Voltage applied to the primary windings of a transformer.
Proton	The particle in the nucleus of an atom having a positive charge.
Pulsating Direct Current	Current which varies in magnitude, but not in direction.
Pulsating Voltage	Varying voltage, the variations of which take place during regular intervals of time and may or may not include changes in polarity.
Pulse	A brief excursion of a quantity from normal; such as a pulsating voltage.

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Pulse-per-second (pps)	The number of pulses of a pulsating voltage in a given length of time. Usually expressed as a frequency of a pulsating voltage.
	-R-
Rate	Measurement of movement per unit of time; e.g., rate of flow, climb, etc.
Rated Output	Output power, voltage, or current, etc., at which a machine, apparatus, or device is designed to operate under specified normal conditions.
Reactance (X)	The opposition offered to the flow of an alternating current by the inductance, capacitance, or both in any circuit. Measured in ohms.
Reactive Load	Load having reactance, such as capacitive load or an inductive load, rather than a resistive load.
Reactive Power	Power given back in any circuit, by the collapsing magnetic field of an inductive reactor; or by the collapse of an electrostatic field of a capacitor or capacitive effect, or the combination thereof. Reactive power is generally expressed as volt-amperes-reactive (VAR) because the term "power" implies the expenditure of unrecoverable energy.
Rectification	The process of changing alternating current to direct current.
Rectifier	A device for converting alternating current to pulsating or full-wave direct current. Full-Wave Rectifier - A device which uses both positive and negative alternations of AC to produce a direct current. Half-Wave Rectifier - A device which converts AC into pulsating DC by allowing current to pass during one alternation of each AC cycle.
Regulator, Carbon Pile	Device for controlling the voltage or current output of generators.
Regulator, Reg Ohm	Varies resistance in the control windings of the positive control mag amp.
Relay	An electromagnetic switch which permits control of a large current in one circuit by a much smaller current flowing in a control circuit.
Reluctance	Opposition to flow of magnetic flux.

Residual Magnetism	The magnetism which remains in a material after the magnetizing force is removed.
Resistance (R)	The opposition to the flow of current caused by the nature and physical dimensions of a conductor.
Resistor	A circuit element whose chief characteristic is resistance; used to oppose the flow of current.
Resistance Wire	Wire made of a metal or alloy having high resistance per unit length, such as nichrome. Used in wire-wound resistors, heating elements, etc.
Resonance	A circuit in which the inductive reactance and capacitive reactances are equal. (In a circuit whose inductive and capacitive elements are in series, the total impedance at the resonant frequency is equivalent to the DC resistance; in a circuit in which the capacitive and inductive elements are in parallel, the impedance reaches a maximum value.)
Retentivity	Ability to hold magnetism.
Rheostat	A variable resistor.
Right Triangle	A triangle which has one 90-degree angle.
Ripple	Periodic fluctuation on a DC voltage which results from incomplete filtering in a power rectifier set, or from the bars of the commutator of a DC generating machine.
Ripple Frequency	The number of pulses or ripples per unit length of time. It is used as an expression of the frequency of a pulsating voltage or current.
Rotor	The part of an electrical machine that turns or rotates.
Rotating Magnetic Field	Name applied to the magnetic field in the stator of AC motors.

-S-

Saturation	In a vacuum tube the condition which exists when an increase in plate potential does not increase electron flow of the tube.
Saturable Reactor	Magnetic core reactor in which a low value of current produces magnetic saturation of the core.
Schematic Circuit Diagram	Circuit diagram in which component parts are represented by simple, easily drawn symbols. May be called a schematic.

Screen Grid	A grid placed between the control grid and the plates. It has positive potential less than the plate and tends to neutralize the capacitive effect between the control grid and the plate.
Secondary Coil	The output winding of a transformer.
Secondary Emission	The emission of electrons from the plate due to the bombardment of electrons from the cathode.
Secondary Voltage	Voltage across the secondary windings of a transformer.
Selenium Rectifier	Rectifier formed of discs of metal in contact with a layer of metallic selenium.
Self Excitation	A generator that receives excitation power from itself.
Self-Inductance	Induction associated with but one circuit.
Self-Induction	1. Action in which a counter electromotive force is produced in a conductor when the conductor's own magnetic field collapses and expands with a change of current flow. 2. Production of a voltage in a circuit as a result of a varying voltage in the same circuit.
Semiconductor	Solid or liquid electronic conductor, with resistivity between that of metals and insulators.
Semiconductor Diode	A diode made of semiconductor materials.
Series Circuit	Two or more units connected with only one path for current through them.
Shell	A group of electrons supposed to form part of the outer structure of the atom, and having a common energy level.
Short Circuit	A low or zero impedance path between two points. A type of electrical trouble wherein the current bypasses the normal unit of resistance in the circuit.
Shunt	A particular type of resistor designed to be connected in parallel with an instrument to extend its current range beyond the value for which the instrument is already complete.
Shunt Wound	A motor or generator wound so that the armature and field are in parallel.
Signal	Any transmitted electrical impulse.

Silicon	Nonmetallic element which is a semiconductor used in the manufacturing of transistors.
Sine Curve	The graph obtained by plotting the sine of an angle against degrees.
Sine of an Angle	One of the trigonometric functions of an angle in connection with a right triangle; the ratio of the side opposite the angle to the hypotenuse.
Sine Wave	The waveform of pure alternating current showing the buildup to maximum value and the falling off to zero of both negative and positive alternations.
Slip	The difference between synchronous speed and actual speed of the rotor of an induction motor.
Slip Rings	Copper rings which complete a circuit to a rotating member through brushes. May be used for either AC or DC circuits.
Solenoid	A coil of insulated wire wound in the form of a spring or on a spool.
Space Charge	A negative charge in a vacuum tube due to free electrons which are not attracted to the plate.
Specific Gravity	The ratio of the weight of a given volume of any substance to the weight of the same volume of pure water.
Spark	Flash due to an electric discharge through air or some other dielectric material, taking place between two or more electrodes.
Squirrel Cage Windings	Short circuited windings with its conductors joined by a continuous end ring.
Static	Fixed, nonvarying, non-moving condition.
Static Electricity	An electric charge caused by friction of two dissimilar materials, generally found in nature.
Stator	A stator is the part of an AC generator or motor which has the stationary winding on it.
Step-Down Transformer	Transformer in which the energy transfer is from a high voltage winding to a low voltage winding or windings.
Step-Up Transformer	A transformer in which the energy transfer is from a low voltage winding to a high voltage winding or windings.

Subatomic Particles	Particles which make up the atom. Proton, neutron and electron.
Switch (SW or S)	A device for closing, opening, or changing the connections of a circuit.
Switching	Making, breaking, or changing the electrical connections of a circuit.
Symbol	In circuit diagrams, a conventional sign, such as a letter, a character, or an abbreviated word used as a circuit part.
Synchronization	The process of bringing two or more AC units in phase with each other.
Synchronous	Moving in perfect time or step.
Synchronous Motor	A motor which turns at the same speed as the rotating magnetic field.

-T-

Tank Circuit	An inductor and capacitor in a parallel connected resonant circuit. Since such a circuit has the ability to store energy for a short period of time, it acts as a reservoir or tank.
Tap	A connection brought out of a winding of a transformer at some point between its extremities, usually to permit changing of the voltage ratio.
Tapped Resistor	Wire-wound, fixed resistor having one or more additional terminals along its length generally for voltage divider applications.
Terminal	A point to which electrical connections are made.
Test Jack	Appearance of a circuit or circuit element in jacks for testing purposes.
Test Lead	Flexible insulated lead used chiefly for connecting meters and test equipment to a circuit under test at a test point.
Test Prod	Sharp metal point provided with an insulated handle and means for electrical connection to a point under test. It is used for making touch connections to a circuit.
Tetrode	A four-element vacuum tube.
Thermionic Emission	The emission of electrons from a heated cathode in a vacuum tube.

Thermocouple	A joint of two dissimilar metals across which a DC voltage is produced when heated.
Thyratron	A mercury vapor tube containing a grid by means of which relatively high currents can be controlled.
Toggle Switch	A manually operated lever type switch.
Torque	A twisting or turning force.
Transformer (T)	A device for transferring electrical energy from one circuit to another. It may step up the voltage and step down the current or vice versa. In any particular case the total energy transferred remains the same, except for copper loss, eddy currents and hysteresis.
Transistor	Active semiconductor device with 3 or more electrodes.
Triode	A three-element vacuum tube.
True Power (P_t)	The power actually consumed in an AC circuit and equal to I^2R. Measured in watts.
Turn Ratio	The ratio of the number of turns in a primary winding of a transformer to the number of turns in the secondary winding.

-V-

Vacuum	An inclosed space from which practically all air has been removed. (A perfect vacuum is not obtainable.)
Vacuum-Tube Voltmeter	(VTVM) device utilizing the characteristics of a vacuum tube for measuring voltages.
Valence	Measure of the extent to which an atom is able to combine directly with other atoms. It is believed to depend on the number and arrangement of the electrons in the outermost shell of the atom.
Valence Band	The range of energy states in the spectrum of a solid crystal in which lie the energies of the valence electrons which bind the crystal together.
Variable Capacitor	Capacitor whose capacitance can be varied from maximum to minimum value by mechanical means.
Variable Inductor	Coil in which the inductance value can be varied by mechanical means.
Variable Resistor	Wire-wound or composition resistor, the value of which can be changed by mechanical means.

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Variac	Trade name for an autotransformer with a toroidal winding with a rotating carbon brush, giving a continuously adjustable voltage from zero to line plus 17 percent.
Varmeter	Meter used to measure reactive power in an electrical circuit. Measures volt-amp-reactive; measures all of the volts of the circuit times all of the out-of-phase amps or current.
Vector	A line which by length shows amount of a quantity to scale and whose arrow represents direction or angle of the quantity.
Vibrator	A mechanical-electrical device used to change a continuous steady current into a pulsating current.
Volt (v)	Unit of electromotive force or electrical pressure. One volt is the pressure required to send 1 ampere of current through a resistance of 1 ohm.
Voltage	Term used to signify electrical pressure. Voltage is the force which causes current to flow through an electrical conductor. Voltage of a circuit is the greatest difference in potential between any two conductors of the circuit concerned.
Voltage Drop	A part of the applied voltage used up in a particular part of a circuit. In a simple circuit the voltage drop across the unit of resistance would equal the applied voltage.
Voltage Rating	The maximum sustained voltage that can be safely applied to an electrical device without risking the possibility of electrical breakdown.
Voltage Regulator	A device used in connection with generators to keep the output voltage constant as load or speed is changed.
Voltage Sensing Coil	Coil in the carbon pile regulator which senses and compensates for a voltage drop.
Volt-Ampere (VA)	The unit of apparent power in an AC circuit.
Volt-Amp-Reactive (VAR)	The unit of reactive power; the product of the out-of-phase voltage and current.
Voltmeter	Instrument for measuring potential difference or voltage. It may be calibrated in volts, millivolts, or kilovolts.

Watt	Practical unit of electrical power. It is the power required to do work at the rate of 1 Joule per second. In a DC circuit, the power in watts is equal to the voltage multiplied by the current in amperes. In an AC circuit, the true power in watts is the effective voltage multiplied by the circuit power factor. (Note) 746 watts = 1 horsepower.
Wattage Rating	Rating expressing the maximum power that a device can safely handle.
Wattmeter	An instrument for measuring true power.
Wavelength	The distance between two corresponding phases of two consecutive waves of a wave train. It is usually expressed in meters.
Weight	The force with which a body is attracted toward the center of the earth by gravity.
Winding	One or more turns of wire forming a continuous coil for a transformer, rotating machine, or other device.
Wire	Solid or stranded group of solid, cylindrical conductors having low resistance to current flow, with any associated insulation.
Wire-wound Resistor	Resistor utilizing, as the resistive element, a length of high resistive wire or ribbon wound on an insulating form.
Wiring Diagram	Drawing that shows electrical equipment and/or component parts together with all the wiring that connects this equipment and/or parts.
Work	The result of a force acting against opposition to produce motion and is measured in terms of the product of the force and the distance it acts.
Working Voltage	Voltage rating. In a capacitor it is the maximum that the device can withstand under normal operating conditions.
Wye	Method of connecting the stator windings in a 3 phase motor or generator.

-Z-

Zener Breakdown	In a semiconductor diode, a breakdown that is caused by the field emission of holes and electrons in the depletion layer.

PROGRAMMED TEXT
3ABR42331-PT-104
3ABR42334-PT-103

Technical Training

Aircraft Environmental System Mechanic
Aircraft Pneudraulic System Mechanic

SAFETY

7 September 1977

3350 TECHNICAL TRAINING WING
3370 Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE
DO NOT USE ON THE JOB

FOREWORD

This programmed text was prepared for use in the 3ABR42331 and 3ABR42334 Instructional Systems and was validated using students enrolled in the subject courses. At least 90 percent of the students achieved the objectives as stated. The average time required to complete this text is 55 minutes.

OBJECTIVES

1. Select the safe work habits and procedures consistent with shop and flight line safety.

2. Select general housekeeping procedures which are consistent with shop, flight line, and fire protection.

3. Select protective measures used against radiation hazards.

4. Select the protective measures used against high frequency transmission equipment.

5. Select the safety precautions that will be observed while working around danger areas.

Note: The above objectives will be accomplished with a minimum of 80% accuracy.

6. Select the protective devices used for protection from high intensity sound without error.

7. Select the marking applicable to radioactive parts and materials.

INSTRUCTIONS

This programmed text presents information in small steps called "frames." Carefully study each frame until you understand its contents. You are required to identify or complete or match items to related situations. Specific instructions are given in each frame. Check the accuracy of your work by looking at the answer at the bottom of the following frame. If your response is incorrect, read the frame again and correct your error before going to the next frame. DO NOT HURRY!

Supersedes 3ABR32531-PT-105, 3ABR42230-PT-105, 3ABR32530-1-PT-803, 3ABR32632B-PT-202, 3ABR42132-PT-103, 3ABR42231-PT-106, 19 July 1973.
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GROUND SAFETY

Frame 1

Most accidents don't just happen. They are caused by unsafe acts of people. Safety education is the most effective tool in preventing these acts. Training is a particularly important accident prevention control; it gives each man a personal safety tool by developing habits of safe practice and operation. The principal objective of any safety program is to provide safe operating standards for ground operations that will aid in eliminating accident-causing sources.

Check the correct statement(s).

1. _____ Most accidents are "man made" and can be controlled.

2. _____ Adequate safety education is the most effective way of preventing "man made" accidents.

3. _____ Training usually is ineffective in preventing accidents.

4. _____ One principal objective of any safety program is to eliminate accident-causing sources.

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Frame 2

Accident prevention is the responsibility of management personnel such as commanders and supervisors. However, the person most responsible for your own safe work habits and attitudes can only be yourself. Unless you develop safe work habits and constantly practice safety, you or your fellow workmen may be injured.

Check the correct statement(s).

1. _____ If you are involved in an accident, you should always blame your supervisor.

2. _____ Being completely familiar with safe work procedures does not insure against accidents.

3. _____ Accident prevention is the responsibility of management personnel.

4. _____ You are responsible for your safe work habits.

Answers to frame 1:

1. ✓ 2. ✓ 3. _____ 4. ✓

Frame 3

Accidents involving handtools are usually the result of misuse. Just because handtools are simple devices does not mean they can be used safely by anyone with little or no training. Therefore, prevention of accidents involving handtools becomes a matter of proper instruction and adequate training in safe working practices.

Check the correct statement(s).

1. _____ Proper instruction is better than experience when learning to use handtools.

2. _____ Simple handtools are not dangerous; it is only their misuse that causes accidents.

3. _____ You should be taught handtool safety before using them.

4. _____ The misuse of handtools is not a violation of safety rules.

Answers to frame 2:

1._____ 2.__✓__ 3.__✓__ 4.__✓__

230
Frame 4

Screwdrivers are probably the most commonly used handtool. They are used for one purpose -- to loosen or tighten screws. If used for other purposes, they are misused. Common misuses of screwdrivers are as follows:

1. punches.
2. chisels.
3. pinch bars.
4. prys.
5. nail pullers.
6. hammers.
7. wedges.
8. scrapers.

The misuses listed above are dangerous to personnel, as well as damaging to the screwdrivers which makes them unsafe for further use.

Check the correct statement(s).

1. _____ You may misuse a screwdriver as long as you think it is a safe act.

2. _____ Damaged screwdrivers must not be used.

3. _____ Screwdrivers are designed for use on screws.

Answers to frame 3:

1. ✓ 2. ✓ 3. ✓ 4. _____

Misuse of files presents a safety hazard because of sharp cutting surfaces, tanged (pointed) ends, and brittle metal. The following safety practices will be observed when using files:

1. Do not use files without handles as pointed tangs can stab or cut your hand.

2. Clamp the work to be filed in a vise, never hold it in your hand while filing.

3. Do not use a file for a pry bar. The tang end is soft and will bend, while the body is hard and brittle and may snap.

4. Never hammer on a file. Remember, a file is brittle and may chip, splinter, or snap, scattering sharp fragments.

5. Old files should never be reshaped into knives, chisels or punches. They are too brittle to use for these purposes. Unexpected breaks could be dangerous.

Check the correct statement(s).

1. _____ You should not use a file without a handle.

2. _____ Files make good knives.

3. _____ An important reason for not misusing a file is the danger of breaks and chips.

Answers to frame 4:

1._____ 2. ✓ 3. ✓

237

Frame 6

Wrenches are frequently misused resulting in injury to personnel. The following practices will be observed concerning their safe use:

1. Use a wrench of the correct size. A loose wrench may slip and injure the hand.

2. Do not use wrenches with spread or distorted jaws, bent handles, or cracks.

3. Do not use a wrench as a hammer. To do so will weaken it.

4. Do not use a pipe or other device on a wrench handle for greater leverage. The wrench handle may snap and cause injury to personnel.

5. Never hammer on wrench handles to free frozen nuts.

6. Pull a wrench - never push it. You can maintain your balance easier by pulling.

Check the correct statement(s).

1. _____ Wrenches are not dangerous, it is only their misuse that is dangerous.

2. _____ If a wrench jaw is cracked, it may as well be used until it breaks.

3. _____ A wrench of the correct size, when used properly, will not slip.

Answers to frame 5:

1. ✓ 2. _____ 3. ✓

Frame 7

Hammers should be kept clean and free of oil or grease which would cause the handle to slip from the workman's hand or cause the hammer to glance off the object being struck. The ends of hammer handles will not be used for prying, pounding or tapping. This practice may damage and weaken the handle and lead to an accident.

Check the correct statement(s).

1. _____ Hammer heads should be kept greased to prevent rust.

2. _____ You should never put oil on hammer handles.

3. _____ You should not tap work with the end of a hammer handle.

Answers to frame 6:

1. ✓ 2. _____ 3. ✓

The following safety rules apply to knives:

1. Keep knife blades sharp. Dull blades contribute to more accidents than sharp blades.

2. Use knives for cutting, never for a screwdriver or pry bar.

3. Do not leave knives lying around where they may cause injury. Keep pocket knives folded (closed) when not in use.

4. Cut away from the body, being careful to cut in a direction that will not endanger fellow workers should the knife slip.

Check the correct statement(s).

1. _____ If you sharpen a pencil with a pocket knife, place the end of the pencil on your thumb and cut toward your thumb.

2. _____ Pocket knives are dangerous unless used properly.

3. _____ Dull blades are more hazardous than sharp blades.

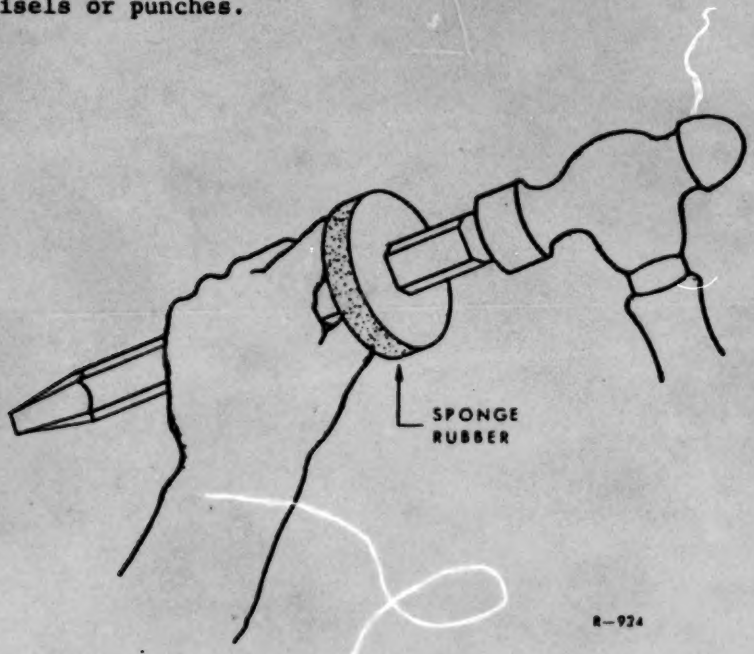
4. _____ Knives may be used for many jobs other than cutting.

Answers to frame 7:

1._____ 2. ✓ 3. ✓

Punches and cold chisels will be kept free from grease and oil to prevent slippage. Hold these tools between the thumb and four fingers. If tools have become mushroomed they must be properly dressed or ground. If practical, hand guards such as sponge rubber will be used.

Workers will wear safety goggles or face shields whenever they strike chisels or punches.



Check the correct statement(s).

1. _____ A chisel becomes mushroomed on the end opposite from the cutting edge.

2. _____ Chisels cut better when the cutting edge is greased.

3. _____ Mushroomed punches should be dressed by grinding.

Answers to frame 8:

1._____ 2.__✓__ 3.__✓__ 4._____

236

Frame 10

Pliers and diagonal cutting pliers are often used around electrical equipment. Electrical equipment must be turned off when using these tools on electrical circuits. Pliers must not be used to tighten or loosen bolts and nuts. To do so may damage the bolt head or nut. Wrenches used on bolts or nuts thus damaged may slip and injure the hand.

Check the correct statement(s).

1. _____ Diagonal cutting pliers may be used on electrical circuits only after the electrical system is turned off.

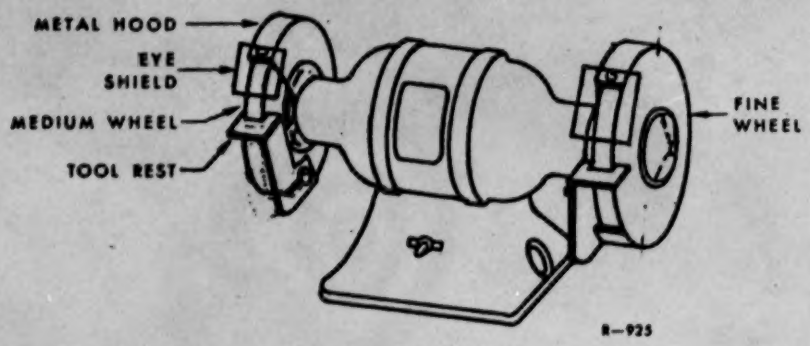
2. _____ You must not use pliers to loosen nuts. /

3. _____ You may use pliers on electrical equipment when the circuit is turned on if you wear rubber gloves.

Answers to frame 9:

1. ✓ 2. _____ 3. ✓

Unsafe grinding practice can result in many serious injuries. In addition to the shatterproof glass shields, workers will wear protective goggles or face shields while operating grinding wheels. You must never operate a grinder with the metal hoods removed. Tool-rests will be adjusted to not more than one-eighth inch from the grinding wheel.



Check the correct statement(s).

1. _____ You must wear goggles or a face shield when grinding on an electrical grinder.

2. _____ While grinding large objects, you should remove the metal hood.

3. _____ Before grinding you must check the distance between the grinding wheel and tool-rest.

Answers to frame 10:

1. ✓ 2. ✓ 3. _____

~~243~~

Compressed air must be handled with care. If you use compressed air for cleaning parts you must wear eye protective equipment, such as goggles. It must never be used to blow dust from clothing or skin. Pressures as low as 10 to 15 pounds per square inch can cause serious injury to skin, eyes, ears, and penetrate the body. Horseplay with the air hose will not be tolerated. Under no circumstances will compressed air be directed toward a fellow worker.

Check the correct statement(s).

1. _____ You must use eye protectors or goggles while cleaning parts with compressed air.

2. _____ Compressed air must not be used to blow dust from your hair.

3. _____ Ten pounds of air pressure is too low to cause personnel injury.

Answers to frame 11:

1. ✓ 2. _____ 3. ✓

Frame 13

Degreasing solvents are used to remove grease from parts. Some of these agents are poisonous when in contact with the skin, taken internally, or inhaled. Trichloroethylene, a nonflammable degreasing solvent, is a narcotic and anesthetic material. An accumulation in the body, due to prolonged exposure, can cause anemia and liver damage. Use trichloroethylene outdoors or in a well ventilated building. You must not expose your skin to this solvent or breathe its vapors.

Check the correct statement(s).

1. _____ Trichloroethylene must not come in contact with the skin.

2. _____ You must not breathe vapors of trichloroethylene.

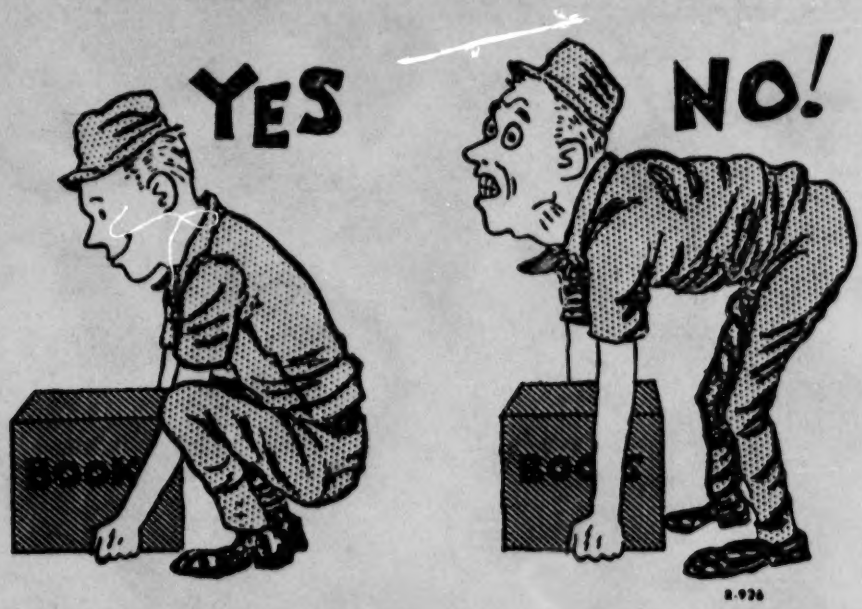
3. _____ Trichloroethylene is not a hazard if skin exposure is for short periods.

Answers to frame 12:

1. ✓ 2. ✓ 3. _____

Frame 14

Hernias, back strains, crushed hands and feet, and broken bones may result from improper lifting. Lift from a squatting position with the back straight. The legs should exert the primary lifting force as shown in the "Yes" figure below.



Check the correct statement(s).

1. _____ When lifting, the back should be the main lifting force.

2. _____ The figure on the left is an illustration of a workman lifting with the legs.

Answers to frame 13:

1. ✓ 2. ✓ 3. _____

Frame 15

You may think it impossible to remember all the safety procedures while performing your daily work. However, it is not difficult to remember that Air Force rules and instructions are written and published for your use. You must use these written rules, regulations, and instructions as you perform your daily work. Do not rely upon your memory when personnel safety is involved. If you perform your work correctly by following written instructions, the possibility of accidents will be reduced. Above all, never engage in horseplay and always use common sense. Keeping these facts in mind will help you perform your daily work in a safe and efficient manner.

No Response Required

Answers to frame 14:

1._____ 2. ✓

242

Frame 16

Check the following statements that are correct.

1. _____ Accidents are sometimes caused by lack of safety training.

2. _____ Each worker is directly responsible for his own safe work habits.

3. _____ Learning to use handtools properly involves training in safe use of handtools.

4. _____ Screwdrivers are handy tools and should be used when other tools such as pry bars and chisels are not available.

5. _____ One hazard connected with misuse of files is possible breakage due to brittle metal.

6. _____ If a nut is "frozen," you should tap the wrench handle with a hammer.

7. _____ A hammer with a split handle should be used until you can get a new hammer or replace the split handle.

8. _____ When cutting with a knife, cut away from the body, not toward it.

9. _____ Danger from mushroomed punches and chisels results from possible hand cuts or flying chips from the tool.

10. _____ Pliers must not be used on bolts and nuts.

11. _____ Grinding wheel tool-rests must be not more than one-eighth inch from the grinding wheels.

12. _____ The principal object of any safety program is to aid in eliminating accident-causing sources.

13. _____ There is no special danger connected with the use of compressed air for cleaning parts.

14. _____ The greatest danger in using trichloroethylene is the extreme fire hazard.

15. _____ You should lift with your legs, not your back.

HOUSEKEEPING AND FIRE SAFETY

Frame 17

Good housekeeping and accident prevention go together. Shops must be kept neat and orderly. All persons must cooperate to keep their work area clean, orderly, and SAFE. Serious accidents could result from tripping over trash, hardware, tools or electrical power cords on floors. Liquids spilled on floors produce slippery surfaces that are particularly dangerous. Keep walking areas clear and clean.

Check the correct statement(s).

1. _____ Possible electrical shock is usually the greatest hazard resulting from power cords lying on the floor.

2. _____ If a tool is dropped on the floor, it should be picked up immediately.

3. _____ Oil on the floor is a source of accidents as well as a fire hazard.

Answers to frame 16:

1. ✓	5. ✓	9. ✓	13. _____
2. ✓	6. _____	10. ✓	14. _____
3. ✓	7. _____	11. ✓	15. ✓
4. _____	8. ✓	12. ✓	

244

Frame 18

Tools must be stored in their proper place, either in the tool kits or on special tools racks. Good habits concerning tool storage and care are essential to efficient and safe job performance. Keep all of your tools in good condition. Clean, sharp, and well selected tools are the mark of a professional systems specialist. Greasy tools used on oxygen equipment are a sure way of causing an explosion and fire.

KEEP OIL AND GREASE AWAY FROM OXYGEN

No Response Required

Frame 19

Lockers, cabinets, shelves, and drawers must be kept neat and orderly. These areas require constant attention as their contents are usually hidden from direct vision. Heavy objects should be stored on bottom shelves to lessen lifting or dropping hazards. Drawers and cabinet doors should not be left open as they usually protrude into the walking area when open.

Check the correct statement(s).

1. _____ Orderly arrangement of drawer and cabinet contents is a safety requirement.

2. _____ Drawers and cabinet doors should not be left open.

3. _____ Lighter objects should be stored on bottom shelves, heavy items on top shelves.

Answers to frame 17:

1. _____ 2. ✓ 3. ✓

Frame 20

Good housekeeping practices are essential to effective fire prevention. Working and living areas must be kept clean and orderly as accumulations of dust, trash, rubbish, and waste are sources of fire. Every man shares the fire prevention responsibility within his working and living area.

Check the correct statement(s).

1. _____ You should not be concerned with good or bad housekeeping practices in your shop because that is the responsibility of your supervisor.

2. _____ Good housekeeping is concerned with cleanliness in the work area.

3. _____ Bad housekeeping practices may cause fires.

Answers to frame 19:

1. ✓ 2. ✓ 3. _____

246
Frame 21

Combustible trash must be placed in closed metal containers that are plainly marked for such materials as shown in the figure below. Lids must be kept closed. At the end of the day or shift, these containers must be emptied or removed to a safe location outside the shop.

NO

YES

8-928

Check the correct statement(s).

1. _____ Noncombustible trash must be placed in closed metal containers.

2. _____ You need not empty trash cans until they are full.

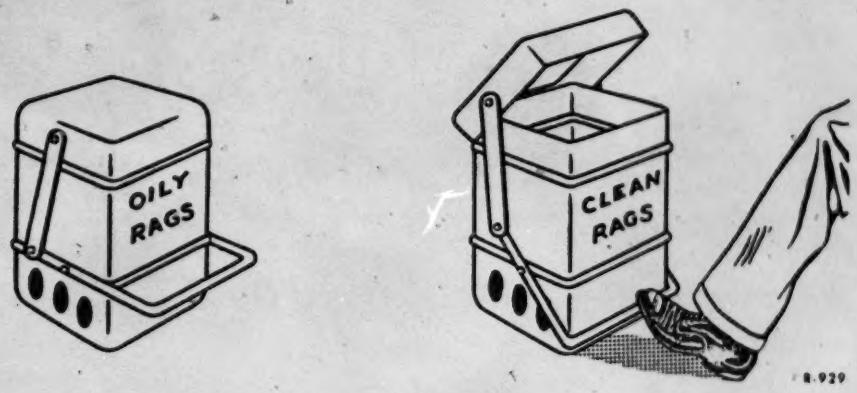
3. _____ Metal trash cans with lids tightly closed may be kept in the shop during working hours.

Answers to frame 20:

1. _____ 2. ✓ 3. ✓

Frame 22

Oil and paint soaked rags must not be placed in trash cans. Self-closing metal containers will be used for this material. A separate closed metal container must be used to store clean rags. Containers will be marked as shown in the figure below. Do not put oily and clean rags in the same container. Care must be taken to prevent oil rags from bursting into flame through spontaneous combustion. Empty the oil rag containers, or place them in a safe location outside the building at the end of each day or shift.



Check the correct statement(s).

1. _____ Trash should not be placed in an oily rag container.

2. _____ Clean rags, in their metal container, present a fire hazard and should be removed from the building at the end of the day or shift.

3. _____ Paint soaked rags should be discarded by placing them in a metal trash can.

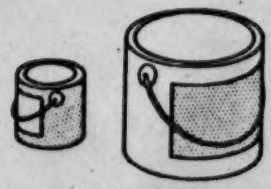
4. _____ Oily rags present a special fire hazard because of possible spontaneous combustion.

Answers to frame 21:

1._____ 2._____ 3. ✓

Frame 23

Oils, paints, cleaning solvents or other volatile liquids must be stored in closed metal containers in designated areas outside of shop buildings. A "safety can" with a flexible spout is a safe container for flammable liquids such as gasoline and cleaning solvents. These containers are shown below.



METAL CANS

SAFETY CAN

Check the correct statement(s).

1. _____ Flammable liquids must not be stored in the shop.

2. _____ Oil does not evaporate rapidly so it may be stored in open cans.

3. _____ Cleaning solvents will be stored in "safety cans."

Answers to frame 22:

1. ✓ 2. _____ 3. _____ 4. ✓

Frame 24

Oil, grease, and other flammable substances spilled on floors will not only create fire hazards, but also slipping hazards. If spills do occur, they must be cleaned immediately with noncombustible absorbents such as sand. Floors will not be cleaned with flammable liquids nor will these liquids be flushed into building plumbing systems and floor drains.

Check the correct statement(s).

1. _____ To reduce fire hazards, water should be used to flush dirty oil down a drain.

2. _____ If you spill a flammable solvent on the shop floor you must clean it up immediately.

3. _____ Gasoline should not be used to clean up spilled oil.

Answers to frame 23:

1. ✓ 2. _____ 3. ✓

250
Frame 25

Liquids such as gasoline, jet engine fuel, and flammable solvents must not be placed in open containers near electrical equipment. Flammable solvents will not be used for cleaning fatigue clothing or used in cigarette lighters. Vapors from these liquids are explosive and may ignite unexpectedly.

Check the correct statement(s).

1. _____ Gasoline may be used for cleaning purposes.

2. _____ Some solvents are flammable.

3. _____ Flammable solvents must not be used near electrical equipment.

Answers to frame 24:

1._____ 2.__✓__ 3.__✓__

Frame 26

Smoking is prohibited in areas in which a match, flame, spark, or careless disposal of smoking material would be a fire hazard. Look for "NO SMOKING" signs in these areas. Where complete prohibition of smoking is impractical, certain areas will be clearly marked and separated from hazardous areas to stop the possibility of fire. Cigarette butts and burned matches must not be placed in trash cans. Special "butt cans" will be provided for this purpose.

Check the correct statement(s)

1. _____ You may smoke in specified smoking areas.

2. _____ You must not smoke in areas where smoking is prohibited.

3. _____ Cigarette butts must be discarded in trash cans.

4. _____ You must not smoke within 50 feet of a hangar or aircraft.

Answers to frame 25:

1.____ 2. ✓ 3. ✓

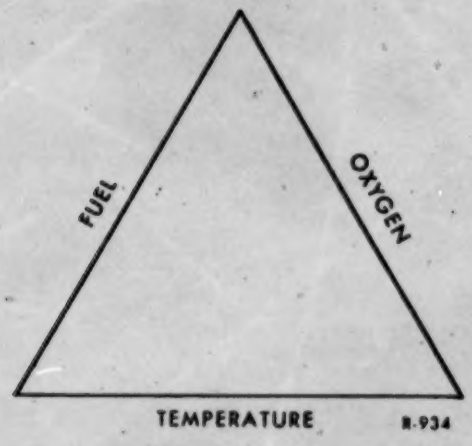
The following ingredients are necessary to produce fire:

1. Fuel (gasoline, wood, paper, rags, etc.).

2. Oxygen (air).

3. Temperature high enough to cause combustion.

Elimination of any one of these will extinguish the fire.



Check the correct statement(s).

1. _____ Gasoline will not burn without oxygen.

2. _____ Oxygen will burn without fuel.

3. _____ A fire may be extinguished by reducing the temperature.

Answers to frame 26:

1. ✓ 2. ✓ 3. _____ 4. ✓

Frame 28

There are three general classes of fires. They are Class A, Class B, and Class C fires. Each fire is classified according to the type of fuel that is burning.

Check the correct statement(s).

1. _____ The class of fire is determined by the ignition temperature of the fuel.

2. _____ Class A, B, and C refers to types of fuel.

Answers to frame 27:

1. ✓ 2. _____ 3. ✓

254
Frame 29

Fires in wood, paper, and rags are typical Class A fires. They will be safety extinguished by cooling or quenching the fire with water.

Check the correct statement(s).

1. _____ Burning waste paper is a Class A fire.

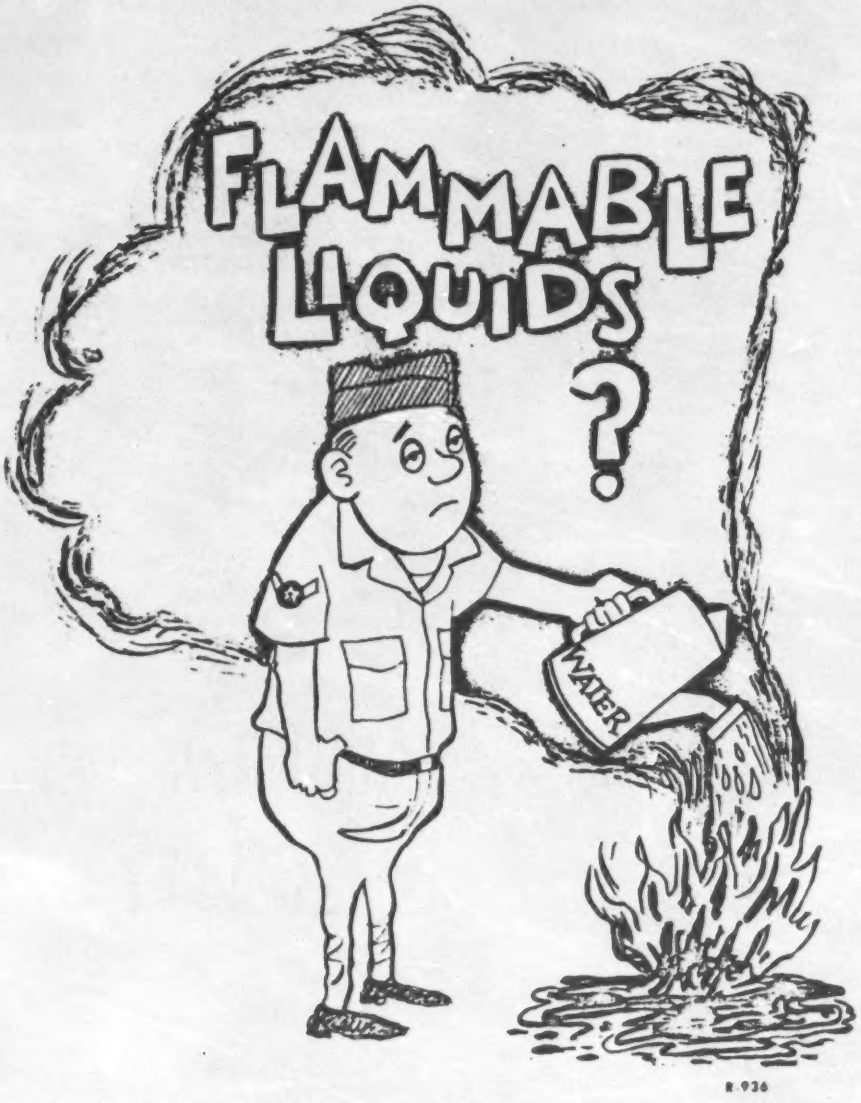
2. _____ Burning gasoline is a Class A fire.

3. _____ Water will spread a Class A fire.

Answers to frame 28:

1._____ 2.✓

Class B fires are fires in flammable liquids such as gasoline, oil, and paint. These fires cannot be extinguished with water. They require fire extinguishers containing smothering agents such as foam.



Check the correct statement(s).

1. _____ Foam cannot extinguish grease fires.

2. _____ Foam is a suitable extinguishing agent for Class B fires.

3. _____ A burning liquid is a Class B fire.

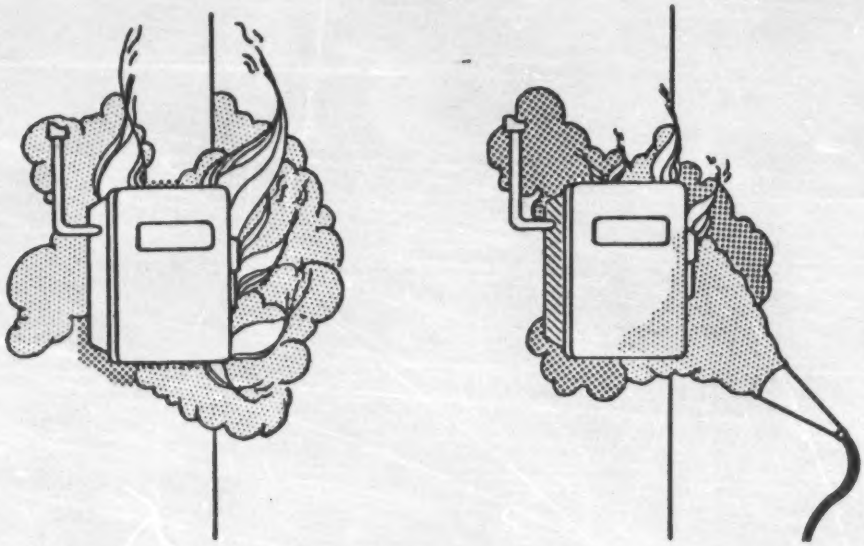
Answers to frame 29:

1. ✓ 2. ____ 3. ____

256

Frame 31

Electrical fires are Class C fires. Electrical shorts in wires, motors, and generators produce heat which causes combustible materials in these electrical units to burn. Electrical fires must be extinguished with nonconducting smothering agents such as chlorobromomethane (CB). Do not use water on electrical fires as water conducts electricity and you could receive a severe or fatal shock.



8-937

Check the correct statement(s).

1. _____ CB should be used on Class C fires.

2. _____ Water may be used on electrical fires.

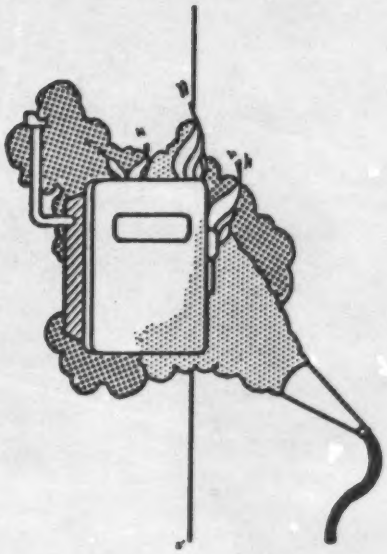
3. _____ Class C fires are electrical fires.

Answers to frame 30:

1._____ 2.__✓__ 3.__✓__

Chlorobromomethane can also be used to smother Class B fires. Remember, the chemical CB can be used on both Class C and B fires. (CB on C and B fires.)

CLASS B FIRE



CLASS C FIRE

R—938

Check the correct statement(s).

1. _____ CB can be used to extinguish oil or an electrical generator fire.

2. _____ Class A fires should be extinguished with CB.

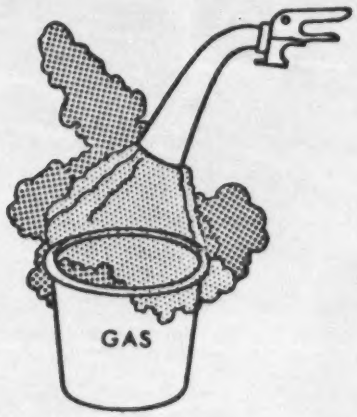
3. _____ CB extinguishes fires by excluding the air from the fuel (smothering the flame).

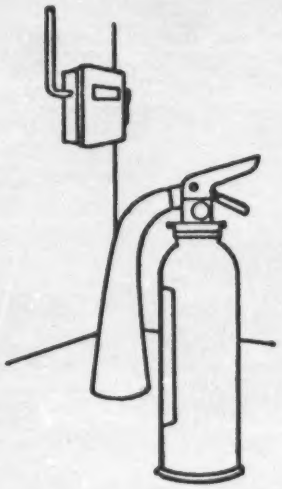
Answers to frame 31:

1. ✓ 2. _____ 3. ✓

Frame 33

Carbon dioxide (CO_2) is another chemical that can be used on Class B and C fires. CO_2 smothers a fire by displacing the air surrounding the fire. CO_2 is a nonconductor of electricity, so may be safely used on electrical fires. It may also be used to extinguish typical class A fires.





B-939

Check the correct statement(s).

1. _____ CO_2 should be used on burning wood.

2. _____ CO_2 smothers a fire.

3. _____ CO_2 or CB may be used to extinguish electrical and flammable liquid fires.

Answers to frame 32:

1. ✓ 2. _____ 3. ✓

Frame 34

Fire extinguishing agents must be directed at the base of the fire, where the combustible vapors combine with air and ignite. "Aim" the extinguisher nozzle at the surface of the material where the flames originate.

Check the correct statement(s).

1. _____ Combustible vapors combine with air at the base of the fire.

2. _____ You should "aim" the extinguisher nozzle at the base of the fire.

3. _____ The base of the fire is the top of the blaze.

Answers to frame 33:

1._____ 2.✓ 3.✓

260

Frame 35

If you report a fire, give your name and location of the fire, and then stand by to direct the fire crews to the fire.

No Response Required

Frame 36

This frame is a review of the material on housekeeping and fire safety. Check the following statements that are correct.

1. _____ There is no relationship between fire prevention and good housekeeping.

2. _____ Gasoline should be used for cleaning parts.

3. _____ Oily rags should be stored in closed metal containers.

4. _____ Fuels, cleaning solvents, and paints should be stored in the shop.

5. _____ Common causes of fires are poor housekeeping and careless use of flammable liquids.

6. _____ Water is a good extinguishing agent for Class A fires.

7. _____ Grease fires are Class B fires.

8. _____ Burning jet fuel should be extinguished with water.

9. _____ Electrical fires are Class A fires.

10. _____ CB is carbon dioxide.

11. _____ Carbon dioxide may be used to extinguish electrical fires as well as flammable liquid fires.

12. _____ Chlorobromomethane may be used on electrical fires.

13. _____ Extinguishing agents should be directed at the top of the blaze to smother the fire.

14. _____ Class B fires can be extinguished by using extinguishers containing smothering agents such as foam.

Answers to frame 34:

1. ✓ 2. ✓ 3. _____

SAFETY PERTAINING TO ELECTRICAL/ELECTRONIC EQUIPMENT

DANGER
HIGH VOLTAGE

Here is a sign many of us are familiar with. Voltages present in shops throughout the world vary somewhat: 110 - 220 - 440, etc.

You will be working on systems that operate on AC and DC voltage. You must be constantly alert for shock hazards, and remember - it takes as little as 10 milliamperes (.01 ampere) of current to prove fatal. Some persons have been fatally injured on even less.

The proper attitude toward electricity is "don't fear it - understand it and respect it."

Check the correct statement(s).

1. _____ Systems with less than one ampere of current flow are not dangerous.

2. _____ Systems with less than one ampere of current flow can be fatal.

3. _____ The amount of voltage in shops may vary from one location to another location.

Answers to frame 36:

1. _____	2. _____	3. ✓	4. _____	5. ✓	6. ✓	7. ✓
8. _____	9. _____	10. _____	11. ✓	12. ✓	13. _____	14. ✓

Frame 38

While working around electrical or electronic circuits you must remove your rings, metal wrist band, watch, or other metallic objects which could act as conductors of electricity and cause shocks, burns, or electrocution. So, form the habit of removing jewelry before doing electrical/electronic work or while performing maintenance on or around aircraft. Repeated exposure to shock may cause bursitis, contraction or dilation in the walls of blood vessels, and muscles can be seriously affected.

R—461

Check the correct statement(s).

1. _____ Severe burns can result from rings, contacting "live" electrical circuits.

2. _____ Wearing a wrist watch on the arm is a potential hazard while working on "live" electrical circuits.

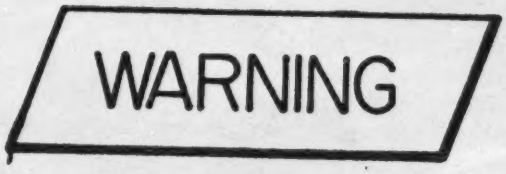
3. _____ Repeated exposure to electrical shock has no after effect on the body.

Answers to frame 37:

1._____ 2.✓ 3.✓

Frame 39

Due to the many different systems that employ electrical/electronic principles, we will not attempt to list the safety precautions that may be involved in each. However, before performing maintenance on these systems, you will comply with all the instructions contained in the appropriate technical orders, manuals, handbooks, and/or applicable directives. Below are examples taken from a technical order on a B-52D type aircraft.



If you observe an individual being electrically shocked, DON'T JUST STAND THERE - DO SOMETHING! First, shutoff the circuit. If the circuit cannot be turned off without delay, free the victim from the live conductor. Remember:

1. DO NOT touch the victim with your bare hands.

2. Protect yourself by using dry insulating material:

a. a dry board, your belt, dry clothing or other non-conducting material.

Check the correct statement(s).

1. _____ An aircraft technical order will list any electrical hazard peculiar to a system.

2. _____ The bare hands should never be used to remove a shock victim from a live circuit.

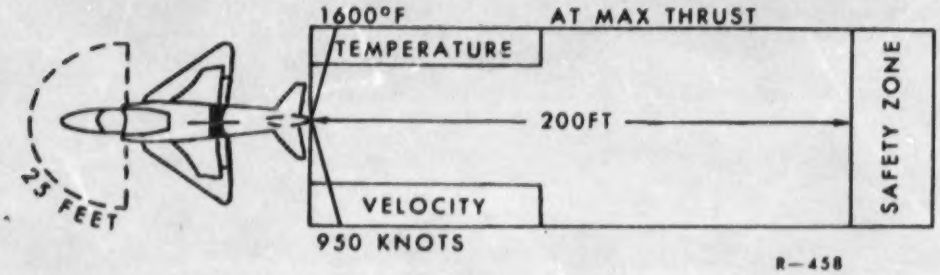
3. _____ A shock victim should not be removed from a live circuit, under any circumstances, until the circuit is turned off.

Answers to frame 38:

1. ✓ 2. ✓ 3. _____

Frame 40

The flight line can be a very interesting and fascinating place due to aircraft taxiing back and forth, some being towed, and others parked on the ramp. In these situations it's easy to forget the hazards that forever lurk about on the flight line. One area where only one mistake can cost your life is the exhaust of an operating jet engine. Directly behind the engine, the temperature is 1600°F, and the velocity is 950 knots. Imagine yourself absent-mindedly stepping behind this death trap. Never come any closer to the exhaust of an operating jet engine than 200 feet, and this includes while you are in a vehicle. Remember, lack of knowledge, improper attitude, and inattention are the real hazards.



Check the correct statement(s).

1. _____ The safe distance behind an operating jet engine is 200 feet.

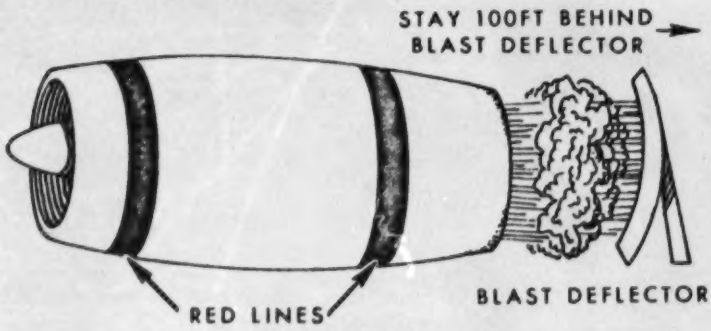
2. _____ Safety is not easily forgotten on the flight line.

3. _____ Temperature and velocity is not a safety factor if the engine is not operating at maximum thrust.

Answers to frame 39:

1. ✓ 2. ✓ 3. _____

If blast deflectors are positioned behind the engine being operated, then it is permissible to come within 100 feet of the exhaust. The blast deflector, besides reducing physical hazards, also prevents nuts, bolts, rocks, sticks, and other rubbish more commonly known as F O's (Foreign Objects) from being blown on to active runways and taxi-ways.



Check the correct statement(s).

1. _____ If deflectors are used, the only hazards that exist are F O's.

2. _____ Using deflectors prevents F O's from blowing on to taxi-ways.

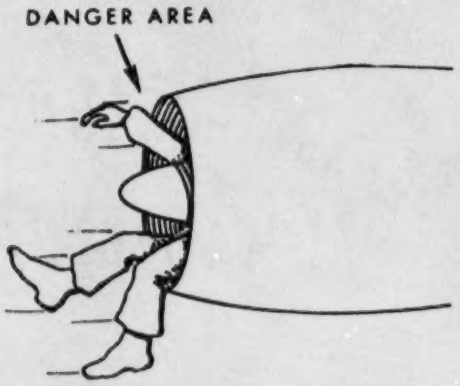
3. _____ 100 feet is a safe distance behind exhausts if deflectors are used.

Answers to frame 40:

1. ✓ 2. _____ 3. _____

Frame 42

Jet engines have huge appetites, and will consume anything in the immediate area. The minimum distance you should be from an operating jet engine intake (see frame 40) is 25 feet. Keep all nuts, bolts, screws, and tools off the intake cowling and out of the reach of the intake. Any one of these items could result in the loss of the aircraft and crew. Always report missing tools which might have fallen into the engine.



R—456

Check the correct statement(s).

1. _____ You should stay 25 feet from the intake of an operating jet engine.

2. _____ If you lose a tool, get it when the aircraft returns.

3. _____ Laying tools on the intake is okay as long as you pick them up later.

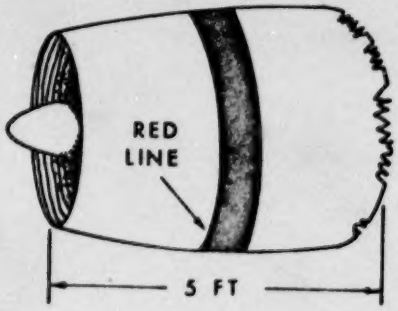
4. _____ Keep all nuts, bolts, and screws picked up.

Answers to frame 41:

1._____ 2.✓ 3.✓

Frame 43

There will be times when you have to work around the engine while it is operating, especially checking systems where test equipment can not simulate an "engine run." If this is the case, you should stay a minimum of 5 feet to the rear of the intake as illustrated in the picture below.



R—457

Check the correct statement(s).

1. _____ You should stay a minimum of 5 feet to the rear of an operating jet engine.

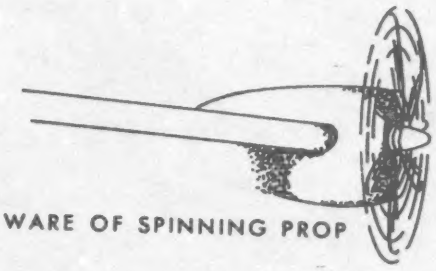
2. _____ You will not work around a jet engine while it is operating.

3. _____ You will be working around the engine while it is operating to check out some of your systems.

Answers to frame 42:

1. ✓ 2. _____ 3. _____ 4. ✓

Devices rotating at tremendously high rpm (revolutions per min) might disintegrate. Therefore, we must be well aware of where these hazards exist. Note the red lines around the engine in frame 43. These indicate the plane of rotation of the engine's turbine wheels. When possible you should stay clear of these areas. On aircraft with reciprocating engines, there will be red lines painted around the fuselage to indicate the planes of rotation of the propellers. The tips of the propellers will be painted yellow so they will be visible while spinning. This is to help prevent someone from walking into them.



BEWARE OF SPINNING PROP

R—460

Complete the following statements.

1. The propeller tips are painted_____in color so they will be _____while spinning.

2. The red bank around the fuselage of a jet engine indicates the _____of_____of the turbine wheel.

3. Devices that rotate at high revolutions per minute are dangerous because they might_____.

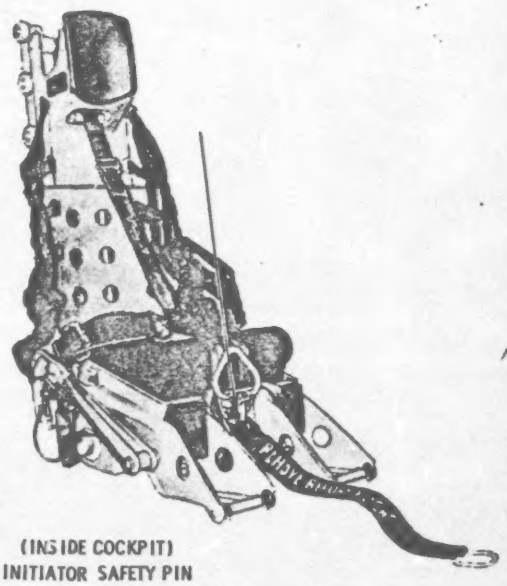
Answers to frame 43:

1._____ 2._____ 3. ✓

Frame 45

Before you enter an aircraft make certain someone has installed the gear down lock safety pins. These pins prevent the aircraft from collapsing on you. They are easily identified by the red streamers attached to them and the words "remove before flight."

Once you have seen that these pins are installed (see photo), look in the cockpit (jet aircraft) and see if similar pins have been installed in the ejection seats. These seats are real killers if you trigger one of them. If they have no pins and streamers -- DON'T GET IN. Notify the crewchief immediately. It takes a specialist that understands them to render the seats harmless. See the photo to the right.



(INSIDE COCKPIT)
INITIATOR SAFETY PIN

Complete the following statement.

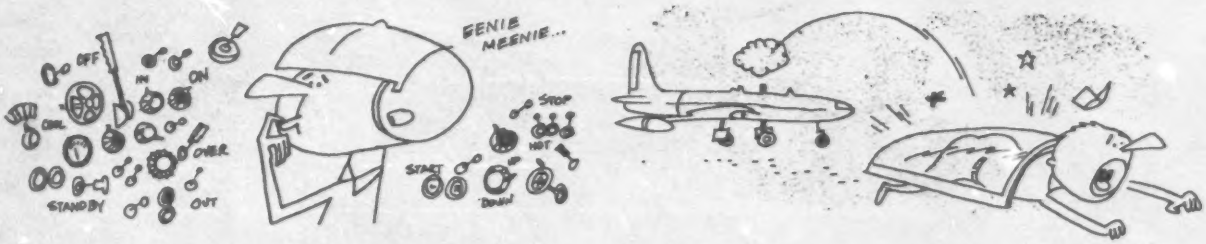
It is permissible to work in the aircraft if red streamers and _____ _____ are instalied in the proper places.

Answers to frame 44:

1. yellow visible (seen or something to that effect)
2. plane of rotation
3. disintegrate (fly apart)

Frame 46

When you must work in the cockpit area, respect your lack of knowledge of other systems. Also, beware of flipping switches, pushing buttons, and moving levers which could cause drop tanks to fall, a drag chute door or speed brake surface to open, or a bomb bay door to close on someone and shear him in half. Usually, a sign will be displayed if an out-of-the-ordinary hazardous condition exists in which someone might be injured.



Complete the following statement:

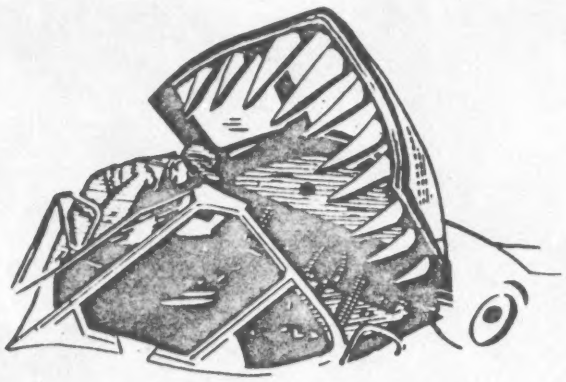
When a job requires you to be in the cockpit area, you should never_____ that is not associated with your systems.

Answer to Frame 45:

Safety Pins

272
Frame 47

Wing and door edges are razor sharp on some aircraft and have been known to cause serious cuts and scars. Wings are extremely slippery after a rain or early morning dew. If you slip from a wing, you can be sure concrete is waiting below. Fast acting canopies account for many accidents involving the amputation of arms and whatever else might get in their way.

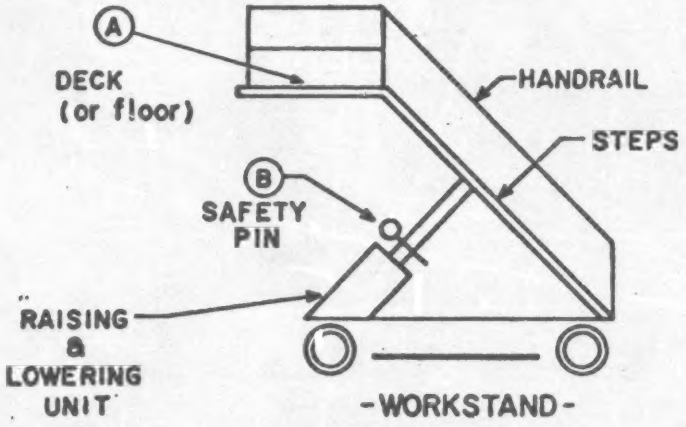


No Response Required

Answer to frame 46:

flip switches, push buttons or move levers (or similar wording).

Work on aircraft frequently calls for the use of maintenance stands. These stands come in an assortment of sizes and designs. Regardless of the purpose for which a particular stand was intended, you will find that once you have climbed aboard, a fall from it could cause serious injury. For this reason, handrails and/or safety pins are provided with them. Stands with removable railings will be in place before maintenance personnel begin working on aircraft from these stands.



The handrail (A) provides a gripping surface and will, if you should stumble, keep you from taking a nasty fall.

The safety pin (B), properly installed in the device that raises the stand into the air, will keep the stand from collapsing with you or on you.

Complete the statement below:

_____ _____ will prevent injury to the user if the lifting system should fail. Injury due to falling over the edge of the stand will usually be prevented by the use of_____.

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Frame 49

Check the statements that are correct:

1. _____ As little as 10 milliamperes of current can be fatal.

2. _____ Watches, rings and other jewelry are shock hazards when working on electrical/electronic circuits.

3. _____ Before working on systems that employ electrical/electronic principles, you should comply with instructions given in technical orders, etc.

4. _____ Temperature and wind velocity is not a safety factor if a jet engine is not operating at maximum thrust.

5. _____ 200 feet is the minimum safe distance behind the exhaust of a jet where blast deflectors are used.

6. _____ The minimum safe distance to be in front of an operating jet engine is 5 feet.

7. _____ You will NEVER work around a jet engine while it is operating (running).

8. _____ The tips of propellers are painted yellow so they may be seen while spinning.

9. _____ Safety pins should be installed in any ejection seat system before entering the cockpit to work.

10. _____ Handrails properly installed on a maintenance stand will prevent the device that raises the stand into the air from collapsing.

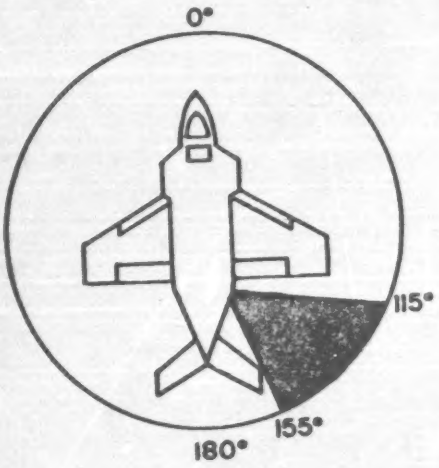
11. _____ The main reason for removing a wrist watch while working on electrical/electronic circuits is to prevent magnetic damage to the watch.

Answer to frame 48:

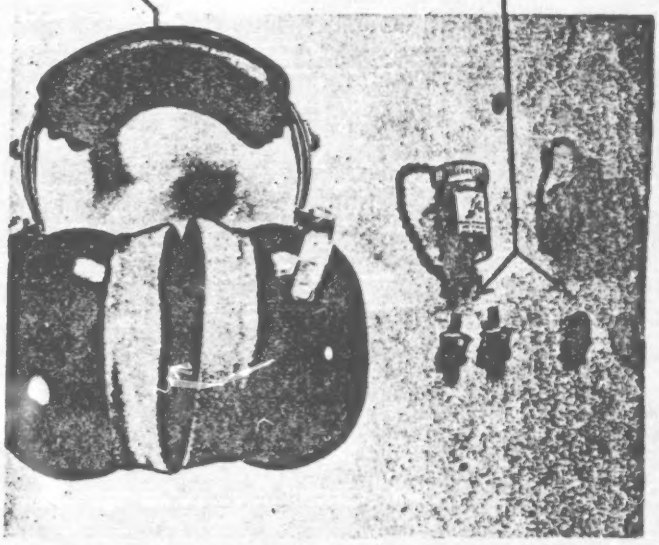
safety pins handrails.

Frame 50

Noise on the flight line is an ever present danger. If not respected, it can cause serious damage to your hearing; sometimes even deafness. The presence of extremely loud noise can interfere with speech communications, hearing, and cause mental and physical "FATIGUE" which in turn can jeopardize your job performance. The Air Force recognizes the seriousness of this hazard, and issues earmuffs and earplugs which must be used when in high intensity noise areas. These devices offer the protection needed while performing your job. The three things that determine the effect noise has on the ears are, intensity, frequency, and duration. The intensity is the greatest at 115° to 155° to the rear of the nose of the aircraft. The unit of measurement of sound (noise) is the "Decible."



"Mickey Mouse" Ear Muffs and Ear Plugs.



Types of ear protectors (defenders)

Check the correct statement(s):

1. _____ Ear protectors should be worn at all times in high intensity noise areas.

2. _____ Wearing earplugs alone offers as much protection as using both muffs and plugs together.

3. _____ Loud noise can cause mental fatigue.

4. _____ Noise intensity is the greatest at 115° to 155° to the rear of the nose of the aircraft.

Answer to frame 49:

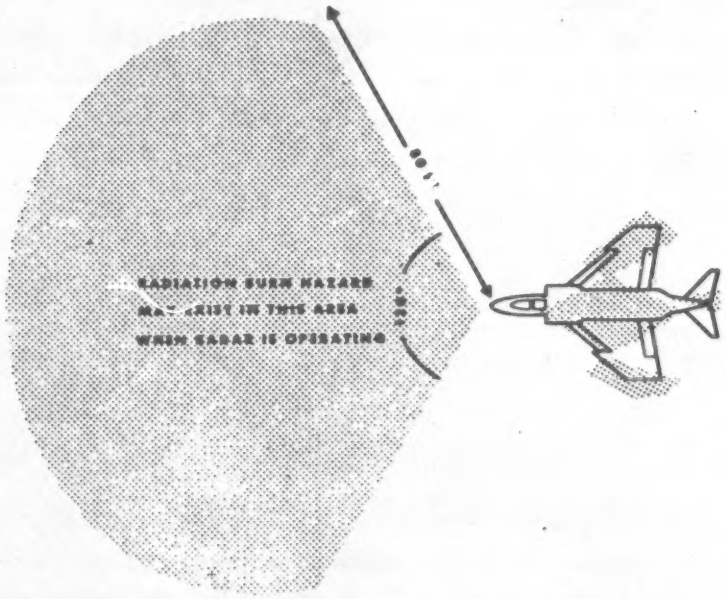
1. ✓ 2. ✓ 3. ✓ 4. _____ 5. _____ 6. _____ 7. _____

8. ✓ 9. ✓ 10. _____ 11. _____

Frame 51

While we are on the subject of sounds and injury, there are sounds above our ability to hear. These are called radio frequency transmissions (electromagnetic radiation is another common expression for it). This radiation is given off by high frequency transmitters (antennaes), such as Radar and Electronic Counter Measure Devices. The source of this hazard is often hidden behind the nose cone of an aircraft; therefore, we may come unsuspectingly in contact with it. The terrific energy radiated by these antennae can cause burns beneath the skin, cataracts over the eyes, and can even cause flash bulbs to ignite and steel wool to burn. The presence of this energy, since it is invisible, may not be readily apparent since burns will result before the pain is felt.

Note: Radiation occurs only along a line directly in front of the antenna; however, some antennae swing in an arc or a circle. For the minimum safe distance, applicable aircraft technical orders should be referred to as the distance will vary from aircraft to aircraft due to the type of systems installed.



The best protection against this unseen menace is to keep to Minimum Safe Distance From high frequency electromagnetic radiation and to steer clear of aircraft and fixed antennae that are in operation.

Check the correct statement(s):

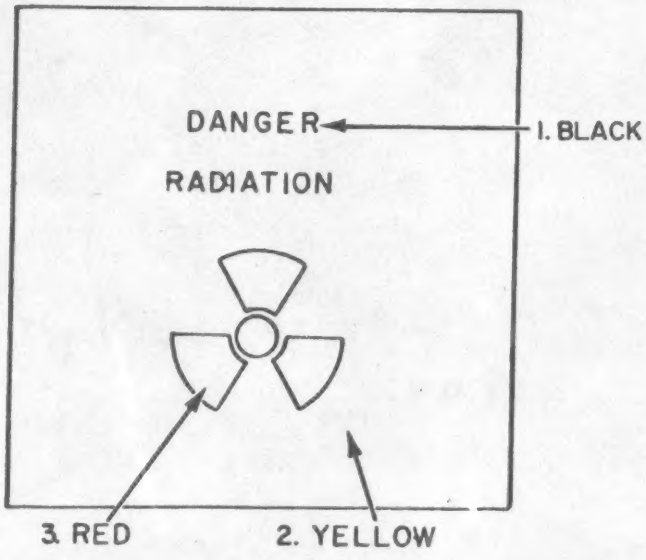
1. _____ Electromagnetic radiation can be seen.
2. _____ Operating transmitters are readily visible.
3. _____ Know the minimum safe distance and you will not be injured.

Answers to frame 50:

1. ✓ 2. _____ 3. ✓ 4. ✓

52

Nuclear (atomic) radiation is probably the least likely hazard to be encountered on the flight line. It might exist, however, in the event an accident should occur while handling one of these weapons or if an aircraft carrying one of them should crash. Then, too, one of our planes may fly through a contaminated zone; and upon its return, require maintenance on one of our systems. However, under normal circumstances, the aircraft will be decontaminated (washed down with soap and water) by the flight line crews before any maintenance is performed. Radiation can be emitted from many other sources, but all sources will be marked by the Radiation Placard shown below. Materials that are radioactive will be so marked that the symbol can be seen from any direction of approach. Study the symbol; its shape and colors.



This symbol appears on AFTO Form 9 and 9 series "B" through "F," and warns personnel of radiation and radioactive hazardous areas or materials.

Check the correct statement(s):

1. _____ If you see the above symbol, but haven't heard an explosion, it is safe to disregard it.

2. _____ AFTO Form 9 warns us of hazards due to high frequency noise.

3. _____ AFTO Form 9 has a red background.

4. _____ AFTO Form 9 series warns us of radioactivity and radiation hazards.

Answer to frame 51:

1._____ 2._____ 3. ✓

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Frame 53

If you should work on or be near contaminated equipment, you will be under the supervision of medical personnel and a monitoring team. In addition, you must wear a film badge or "dosimeter" so the amount of radiation (dosage) you have received can be measured and put in your medical records. You will not be allowed to accumulate too many "Roentgens." The roentgen is the unit of measurement of radioactivity.

Complete the following statement:

Radiation dosage is measured by a_____ _____or_____ and is expressed in units of measurement called_____.

Answer to frame 52:

1._____ 2._____ 3._____ 4. ✓

Frame 54

Cigarettes, cokes, candy, etc, will not be carried or consumed while in a contaminated area. After working in or around a contaminated area, you will shower and be checked to see if you have removed all the radiation particles. If you are completely free of them, you will dress in clean, contamination free clothing. Any waste materials from the cleaning, let's say, from a contaminated aircraft will be disposed of by burial downwind from the maintenance activity. Parts that are radioactive will be marked (Frame 52) with one of the AFTO Form 9 series. One of the early effects of radiation over-exposure is nausea.

Match the terms in column A to the terms in column B by placing the number in the space provided.

Column A		Column B
1. Radiation placard	_____a.	Method of disposing of contaminated waste.
2. Roentgen		
3. Burying	_____b.	Not allowed in contaminated areas.
4. Dosimeter	_____c.	Measures radiation dosage.
5. Smoking	_____d.	AFTO Form 9.
	_____e.	Unit of measurement.

Answers to frame 53:

Film badge or dosimeter Roentgens

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This completes the programmed text on safety. Ask your instructor for the test on the safety information you have just completed.

Answers to frame 54:

3 a. 5 b. 4 c. 1 d. 2 e.

77-46947

Service Test
Programmed Text 3ABR42331-PT-105

Technical Training

Aircraft Environmental Systems Mechanic

AIRCRAFT FAMILIARIZATION

4 October 1978

CHANUTE TECHNICAL TRAINING CENTER (ATC)
3370 Technical Training Group
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ATC FORM 214 (JAN 76) OBSOLETES ATC FORMS 214, MAY 69, 522, NOV 63 AND 523, MAY 71. STANDARD COVERSHEET

FORWARD

This programmed text was prepared for use in the Environmental Pneudraulic Branch, Instructional System. The materials herein were validated with _____ students from the subject course. At least _____% of the students achieved the objectives as stated.

OBJECTIVES

The following objectives pertain to the Aircraft Environmental System Mechanic Course. Students enrolled in the 3ABR42331 course will only accomplish the following objectives.

SECTION I

Select elements used to make up the aircraft designation system with a minimum of 80% accuracy.

SECTION II

Select the terms and elements of the aircraft station numbering system with a minimum of 80% accuracy.

SECTION III

Select major aircraft systems when given their purpose with a minimum of 80% accuracy.

INSTRUCTIONS

Use the response sheet and place all your answers on it. DO NOT WRITE IN THIS BOOK. This program presents information in sections:

SECTION I Aircraft Designation System

SECTION II Aircraft Station Numbering System

SECTION III Major Aircraft Systems

In each section you will find the program presents the information in small steps called "FRAMES". After reading each frame, you are normally asked to select an answer or make an entry that shows you understand the information in that frame. Check the accuracy of your work with the answers supplied at the end of each section. If you responded incorrectly, find out why you missed the question. You can do this by reaccomplishing the frame or the section. If you still continue to have incorrect responses consult your instructor. Insure you have taken corrective measures for your incorrect responses before you move on to the next frame, section test or text. If you have correctly responded, continue working as directed in the program.

After completion of this program texts response sheet (all three sections) consult your instructor so you may be given the test on this program.

Now turn to SECTION I, Frame 1 and begin.

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FRAME 2

AIRCRAFT

DEFINITION - An air vehicle designed primarily for flight in the atmosphere which has incorported in its basic design the ability or requirement for human occupancy.

On the response sheet place "T" for true and "F" for false for the following.

_____1. An aircraft will always have the requirement for human occupancy.

FRAME 3

EXAMPLE ⟶ G R 3 - 52 A 01

BASIC DESIGNATION ⟵

DEFINITION - The minimum combination of letters and numbers required to identify adequately an aerospace vehicle.

On the response sheet place "T" for true and "F" for false for the following.

_____1. Letters are the only things used to identify adequately an aerospace vehicle.

FRAME 4

AEROSPACE VEHICLE DESIGNATION SYSTEM

All military aerospace vehicles will be assigned a basic designation consisting of items listed in Frame 5 through Frame 10, as applicable, in the order shown.

NO RESPONSE REQUIRED

GO TO NEXT FRAME

FRAME 5

EXAMPLE ⟶ G R B - 52 A 01

STATUS PREFIX SYMBOL ⟵

This symbol (letter), if applicable, indicates an aerospace vehicle which is not standard because of test instrumentation, modification, experiment 1, or prototype design. For aircraft, the symbol will be placed at the immediate left of the modified mission symbol or the basic mission symbol in the absence of the former. Attachment 1 contains the authorized status prefix symbols, at the end of this section. Turn to attachment 1 and discover the letter, title and discription which are used for status prefix symbols.

Without looking attachment 1, on your response sheet mark the correct answer for the following.

1. The status prefix symbol "G" shown in the example above has the title,
   a. permanently grounded.
   b. experimental.
   c. prototype.
   d. planning.
2. Experimental arerospace vehicles will use which letter for status prefix symbols?
   a. J
   b. N
   c. X
   d. Y

FRAME 6

EXAMPLE ⟶ G R B - 52 A 01

MODIFIED MISSION SYMBOL ⟵

This symbol will consist of a prefix letter placed at the immediate left of the basic mission of the aircraft. Normally, only one modified mission symbol will be used for any one designation. Attachment 2 contains the authorized modified mission symbols at the end of this section. Turn to attachment 2 and discover the letter, title and discription which are used for modified mission symbols.

Without looking in attachment 2, on your response sheet mark the correct answer for the following.

1. The modified mission symbol "R" shown in the example above has the title,
   a. special electronic installation.
   b. reconnaissance.
   c. transport.
   d. rescue.
2. An aerospace vehicle will use which modified mission symbol letter to identify a tanker?
   a. C
   b. P
   c. K
   d. T

On the response sheet mark "T" for true and "F" for false for the following.

3. _____ The example given above tells you the aircraft has been modified to a reconnaissance aircraft and also has been permanently grounded.

FRAME 7

EXAMPLE ⟶ G R B - 52 A 01

BASIC MISSION AND TYPE SYMBOLS

The basic mission symbol (letter) denostes the primary function of cabability of an aircraft. Mission and type symbols denote the mission and type of aircraft other than fixed wing. An aircraft identified by a type symbol such as "H" for helicopter will be further identified by either a mission symbol or a modified mission symbol, but not both. Attachment 3 contains the authorized basic mission and type symbols at the end of this section. Turn to attachment 3 and discover the letter, title and discription which are used for basic mission and type symbols.

Without looking in attachment 3, on your response sheet mark the correct answer for the following.

1. The basic mission and type symbol "B" shown in the example above has the title,
   a. attack.
   b. bomber.
   c. tanker.
   d. transport.
2. An aerospace vehicle will use which basic mission and type symbol letter to identify a tanker?
   a. C
   b. K
   c. T
   d. X

On the response wheet mark "T" for true and "F" for false for the following.

3. _____ The example given above tells you the aircraft <u>was</u> a bomber and has been modified to a reconnaissance mission and has been permanently grounded.

DESIGN NUMBER

This number denotes changes within the same basic aerospace vehicle. Design numbers will be assigned consecutively beginning with "1" for each vehicle. A dash will be inserted between the basic mission symbol and the design number for all aerospace vehicles.

The above example shows this was originally a B-52 (bomber) aircraft which is the 52nd design number.

Examples:

B-1, B-2, B-3, - - - - -, B-24, B-25, - - - -, B-52, - - - -, B-58, - - B-66, etc.

On the response wheet mark "T" for true or "F" for false for the following.

_____1. The example given below tells you the aircraft was a bomber and modified to refueling aircraft and has been permanently grounded and also is the 52nd tanker in the design number sequence.

EXAMPLE: G R 3 - 52 A 01

FRAME 9

EXAMPLE ⟶ G R B - 52 A 01

SERIES SYMBOL

A letter after the design number denotes the initial production model and follow-on major modifications to an aerospace vehicle. This change is made when it results in significant difference affecting the relationship of the vehicle to the original aircraft production model. Series symbol letters will be assigned consecutively, beginning with "A". To avoid confusion, the letters "I" and "O" will not be used as series letters.

Example:

B-52A, B-52B, - - - - B-52E, B-52F, B-53G, B-52H, - - -etc.

C-130A, C-130B, - - - - - C130E, - - - - C130J, C-130K, - - - etc.

On your response sheet mark the correct answer for the following.

1. In the example GRC - 24D01 which letter is the series symbol.

   a. G

   b. R

   c. C

   d. D

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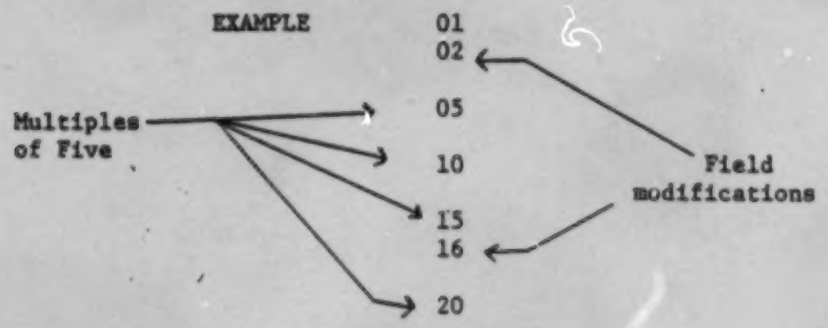
FRAME 10

EXAMPLE ⟶ G R B - 52 A 01

BLOCK NUMBERS

The production block numbering system will consist of the assignment of production blocks, starting at 01, next 05, and progression in multiples of five after 05. Intermediate block numbers will be reserved for field modifications and will be applied by the using military department.

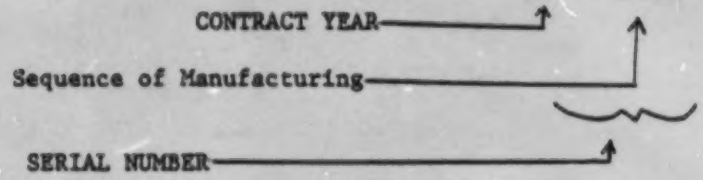


On your response sheet mark the correct answer for the following.

1. The block number in the aircraft designation GRB-52G23 shows that the
   a. production block number is "20" and the intermediate block number for field modifications is "23".
   b. production block number is "23" and the intermediate block number for field modifications is "03".
   c. production block number is "52" and the intermediate block number for field modifications is "02".
   d. production block number is "52" and the intermediate block number for field modifications is "23".

FRAME 11

EXAMPLE——— 63 - 545143



The method of assigning serial numbers is at the discretion of the using military department. As shown in the above example the first two numbers in front of the dash is the contract year of the aircraft. The group of numbers to the right of the dash is the number assigned in the sequence of manufacturing the aircraft.

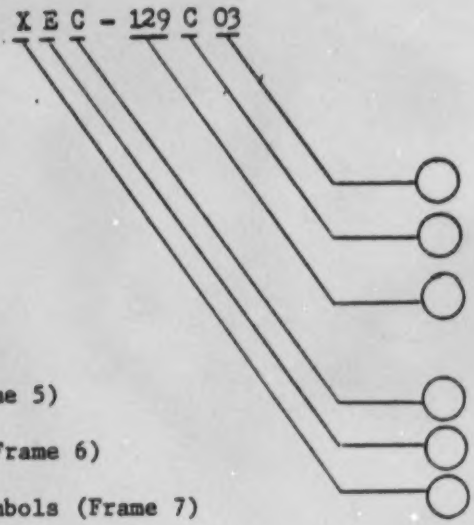
On the response sheet mark "T" for true or "F" for false for the following.

1._____ The contract year is not part of the aircraft serial number.

NOTE: In the three attachments you will find the most common titles underlined.

FRAME 12

Identify each part of the aircraft designation given below. You will do this by selecting the correct identification in column 1, than write its letter in the correct circle under the aircraft designation. DO NOT WRITE ON THIS PAGE. You are to do this work on the response sheet.



Column 1

a. Block numbers (Frame 10)

b. Design number (Frame 8)

c. Series symbol (Frame 9)

d. Status prefix symbol (Frame 5)

e. Modified mission symbol (Frame 6)

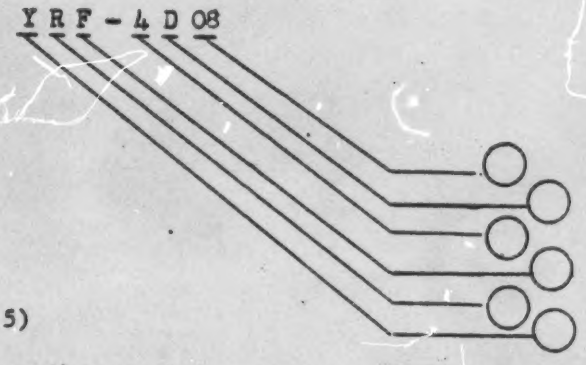
f. Basic mission and type symbols (Frame 7)

NOTE: If you make an error study the required frames as needed before you go to frame 13.

FRAME 13

If you have made an error on frame 12 be sure you restudy the required frame(s) before you start this frame.

Identify each part of the aircraft designation given below. You will do this by selecting the correct identification in column 1, then write its letter in the correct circle under the aircraft designation. DO NOT WRITE ON THIS PAGE. You are to do this work on the response sheet.



Column 1

a. Block numbers (Frame 10)

b. Design number (Frame 8)

c. Series symbol (Frame 9)

d. Status prefix symbol (Frame 5)

e. Modified mission symbol (Frame 6)

f. Basic mission and type symbols (Frame 7)

NOTE: If you make an error in this frame you should go back and restudy frames 1 through 13.

After finishing frames 1 through 13 correctly go on to SECTION II.

STATUS PREFIX SYMBOLS

AEROSPACE VEHICLES

LETTER	TITLE	DESCRIPTION
G*	Permanently Grounded	Aircraft permanently grounded and utilized for ground instruction and training.
J	Special Test, Temporary	Aerospace vehicles on special test programs by authorized organizations or on bailment contract having a special test configuration or whose installed property has been temporarily removed to accommodate the test.
N	Special Test, Permanent	Aerospace vehicles on special test programs by authorized activities or on bailment contract, whose configuration is so drastically changed that return to its original configuration or conversion to standard operational configuration is beyond practicable or economical limits.
X	Experimental	Aerospace vehicles in a development experimental stage where the basic mission symbol and design number have been designated, but not established as a standard vehicle.
Y	Prototype	Aerospace vehicles procured in limited quantities, usually before production decision, to serve as models or patterns.
Z	Planning	Aerospace vehicles in the planning or predevelopment stage.

*Applies only to aircraft

Attachment 1

MODIFIED MISSION SYMBOLS

AIRCRAFT

LETTER	TITLE	DESCRIPTION
A	Attack	Aircraft modified to search out, attack, and destroy enemy land or sea targets, using conventional or special weapons. This symbol also describes aircraft used for interdiction and close air support missions.
C	Transport	Aircraft modified for the carriage of personnel or cargo.
D	Director	Aircraft modified for controlling drone aircraft or a missile.
E	Special Electronic Installation	Aircraft modified with electronic devices for employment in one or more of the following missions: (1) Electronic countermeasures. (2) Airborne early warning radar. (3) Airborne command and control, including communications relay. (4) Tactical data communications link for all nonautonomous modes of flight.
H	Search Rescue	Aircraft modified and equipped for performance of search and rescue missions.
K	Tanker	Aircraft modified and equipped to provide in-flight refueling of other aircraft.
L	Cold Weather	Aircraft modified for operation in the Arctic and Antarctic regions; includes skis, special insulation, and other ancillary equipment required for extreme cold weather operations.
M	Mine Countermeasures	Aircraft modified for aerial mine countermeasures and minesweeping missions.
O	Observation	Aircraft modified to observe (through visual or other means) and report tactical information concerning composition and disposition of enemy forces, troops, and supplies in an active combat area
P	Patrol	Long-range, all-weather, multi-engine aircraft operating from land and/or water bases modified for independent accomplishment of: antisubmarine warfare; maritime reconnaissance; and mining function.
Q	Drone	Aircraft modified to be controlled from a point outside the aircraft.
R	Reconnaissance	Aircraft modified and permanently equipped for photographic or electronic reconnaissance missions.
S	Antisubmarine	Aircraft modified so that it can function to search, identify, attack and destroy enemy submarines.
T	Trainer	Aircraft modified and equipped for training purposes.
U	Utility	Aircraft modified for a capability of performing multiple missions such as battlefield support, localized transport, and special light missions. These aircraft will include those having a small payload.
V	Staff	Aircraft modified to provide accomodations such as chairs, tables, lounge, berths, etc., for transporting staff personnel.
W	Weather	Aircraft modified and equipped for meteorological missions.

Note: Above you will find the most common titles underlined.

Attachment 2

BASIC MISSION AND TYPE SYMBOLS

AIRCRAFT

LETTER	TITLE	DESCRIPTION
A	Attack	Aircraft designed to search out, attack, and destroy enemy land or sea targets, using conventional or special weapons. This symbol also applies to aircraft used for interdiction and close air support missions.
B	Bomber	Aircraft designed for bombing enemy targets.
C	Transport	Aircraft designed primarily for carrying personnel or cargo.
E	Special Electronic Installation	Aircraft equipped with electronic devices for employment in one or more of the following missions: (1) Electronic countermeasures. (2) Airborne early warning radar. (3) Airborne command control including communications relay. (4) Tactical data communications link for all nonautonomous modes of flight.
F	Fighter	Aircraft designed to intercept and destroy other aircraft and/or missiles (includes multipurpose aircraft also designed for ground support missions), for example, interdiction and close air support.
H*	Helicopter	Rotary-wing aircraft designed with the capability of flight in any plane, for example, horizontal, vertical, or diagonal.
K	Tanker	Aircraft designed for in-flight refueling of other aircraft.
O	Observation	Aircraft designed to observe (through visual or other means) and report tactical information concerning composition and disposition of enemy forces, troops, and supplies in an active combat area.
P	Patrol	Long-range, all-weather, multiengine aircraft operating from long and/or water bases designed for independent accomplishment of: antisubmarine warfare; maritime reconnaissance; and mining function.
R	Reconnaissance	Aircraft designed to perform reconnaissance missions.
S	Antisubmarine	Aircraft designed to search out, detect, identify, attack, and destroy enemy submarines.
T	Trainer	Aircraft designed for training personnel in the operation of aircraft or related equipment, and having provisions for instructor personnel.
U	Utility	Aircraft designed with a capability of performing multiple missions such as battlefield support, localized transport, and special light missions. These aircraft will include those having a small payload.
V*	VTOL and STOL	Aircraft designed for vertical takeoff or landing with no takeoff or landing roll, or aircraft capable of takeoff and landing in a minimum prescribed distance.
X	Research	Aircraft designed for testing configuration of a radical nature. These aircraft are not normally intended for use as tactical aircraft.

* Type Symbols

Note: Above you will find the most common titles underlined.

Attachment 3

CORRECT RESPONSES FOR SECTION I

Frame 1

1. F
2. T

Frame 2

1. F

Frame 3

1. F

Frame 4

No response

Frame 5

1. a
2. c

Frame 6

1. b
2. c
3. T

Frame 7

1. b
2. b
3. T

Frame 8

1. F

Frame 9

1. d

Frame 10

1. a

Frame 11

1. F

Frame 12

a
c
b
f
e
d

Frame 13

a
c
b
f
e
d

SECTION II

AIRCRAFT STATION NUMBERING SYSTEM

Frame 1

In this portion of the lesson the station numbering system will be covered.

Military aircraft have become so large and contain so much equipment that it has become necessary to devise a system for locating the various units. No doubt, you are familiar with the way most cities are laid out with two dividing streets intersecting each other at right angles in the heart of the city. Any point in the city can be located with reference to these two lines. The same principle is employed in locating parts of an aircraft except that a third reference line is needed because the aircraft has three dimensions, namely, length, width, and height. Diagrams of the station numbering system, as well as the terms used in the system, are shown and defined in the following grames.

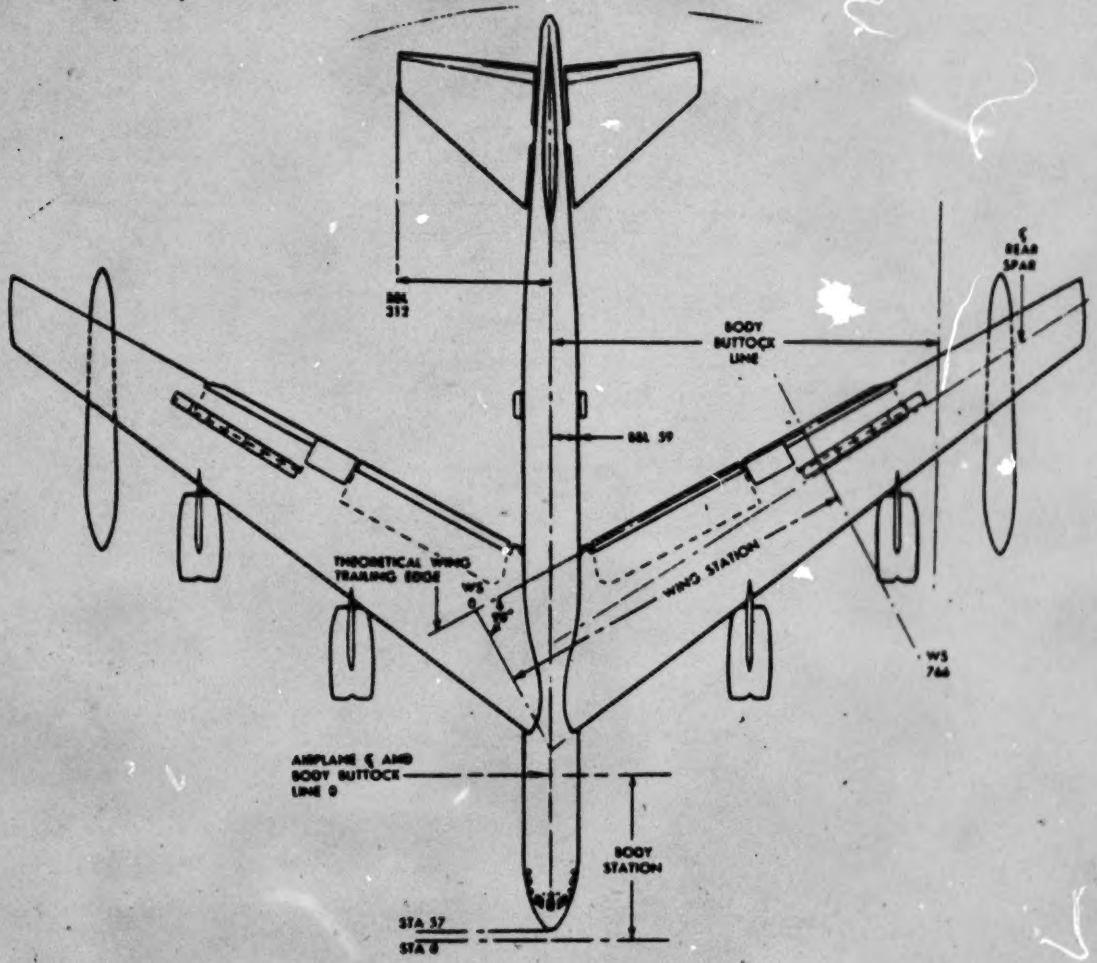
On the response sheet write the correct answer for the following.

The purpose of the station number system is to:

a. aid in the location of various parts or units.
b. aid in the use of the data collection system.
c. be used in the number sequencing of aircraft.
d. aid in the identification of types of aircraft.

FRAME 1 (cont)

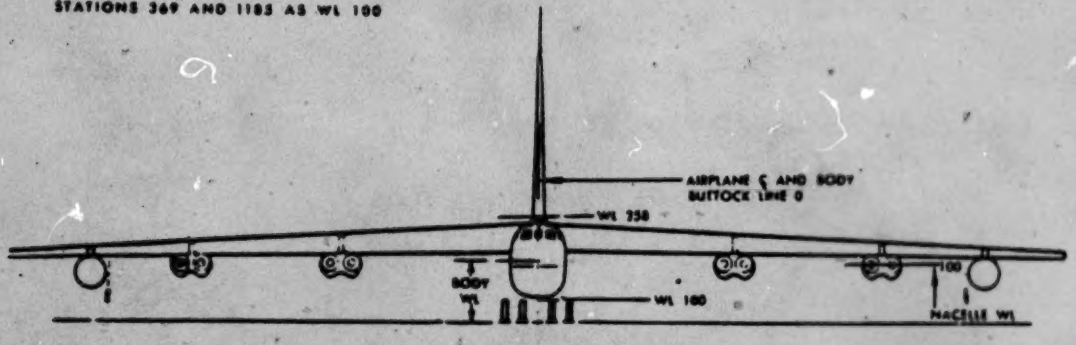
ILLUSTRATION FOR FRAME 1



BBL—BODY BUTTOCK LINE, DISTANCE IN A HORIZONTAL PLANE MEASURED FROM THE VERTICLE ℄ OF THE AIRPLANE BODY IN EITHER DIRECTION

WL—WATER LINE, DISTANCE MEASURED ABOVE A HORIZONTAL DATUM WITH THE BOTTOM OF THE BODY BETWEEN BODY STATIONS 369 AND 1183 AS WL 100

BS—BODY STATION, DISTANCE FROM A POINT 37 INCHES FORWARD OF THE NOSE TO A PLANE PERPENDICULAR TO THE BODY ℄ IN INCHES

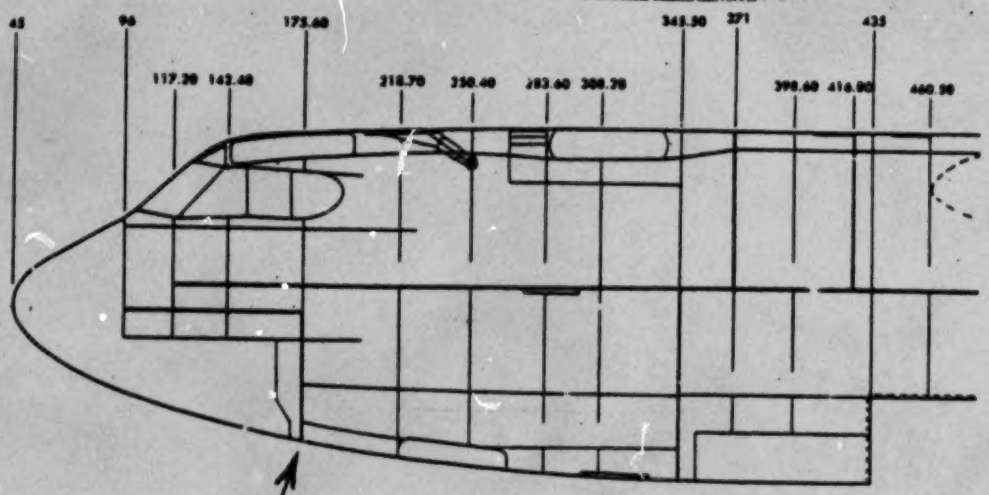


Airplane Station Nomenclature Diagram.

302

Frame 2

Sta 0



Body Station Diagram.

EXAMPLE: This is 175.60 inches from station "0" forward of the nose.

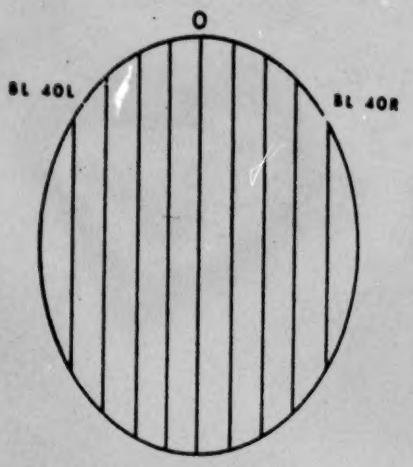
Body stations (BS) are distances measured in inches from a point forward of the nose (STA 0) aft along the fuselage to the tail of the aircraft. These stations are planes cutting through the fuselage at right angles, which are then numbered. The number of a station tells how many inches it is from station 0. The station 0 being forward of the nose allows for aircraft to be lengthened without changing the station numbering system.

Frame 2 (cont)

On the response sheet mark the correct answer for the following.

1. Distances from a point forward of the nose of an aircraft aft along the fuselage to the tail, are called
   a. Water Lines (WLs).
   b. Body Buttock Lines (BBLs).
   c. Body Stations (BSs).
   d. Reference Datum Lines (RDLs).
2. Body station number 180 means that
   a. station is 180 inches from previous station.
   b. station is 180 inches from tail section of the aircraft.
   c. station is 180 inches from station "0".
   d. 180 is just any number assigned with no additional meaning.

Body Buttock Lines (BBLs) are distances measured in inches, right and left from the vertical centerline of the fuselage. These lines run parallel to the vertical centerline and are numbered just as fuselage body stations are numbered. Those on the left of the centerline are indicated by the letter "L" and those on the right by the letter "R".



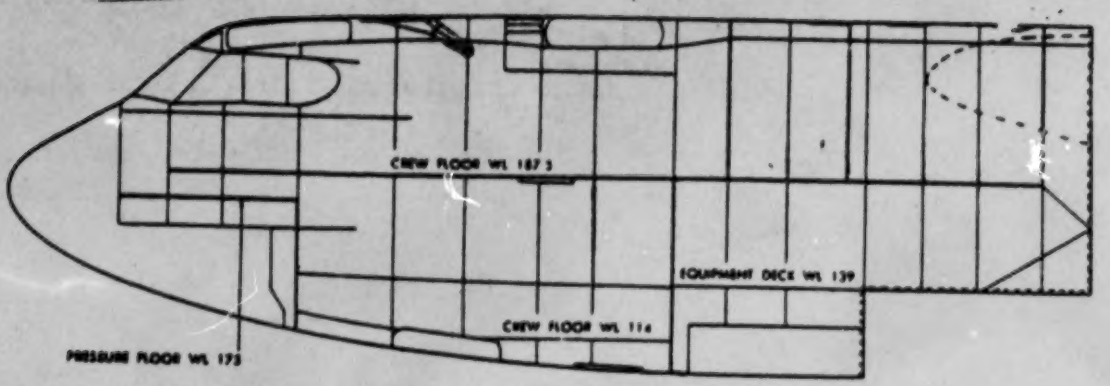
Body Buttock Lines.

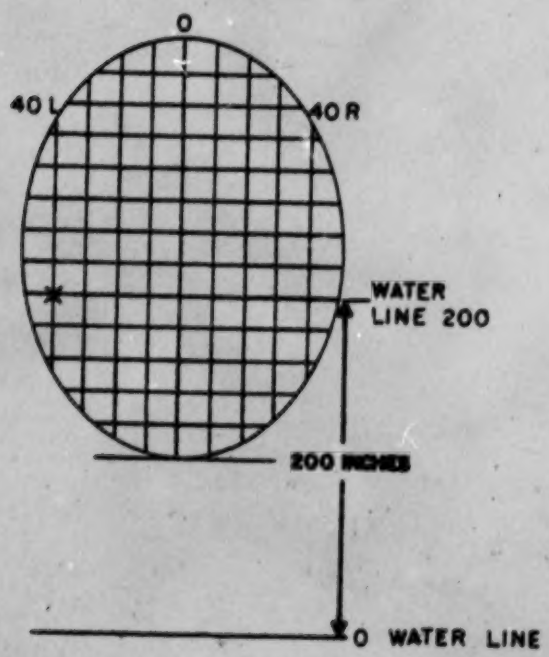
On the response sheet write the correct answers for the questions below.

_____1. Body Buttock Lines are measured in inches for and aft of the horizontal centerline of the aircraft.

_____2. BBL 40L means that this Body Buttock Line is located on the left side of the fuselage and is 40 inches long.

_____3. BBL 40R means that this Body Buttock Line is located on the right side of the fuselage and is located 40 inches from the vertical centerline.





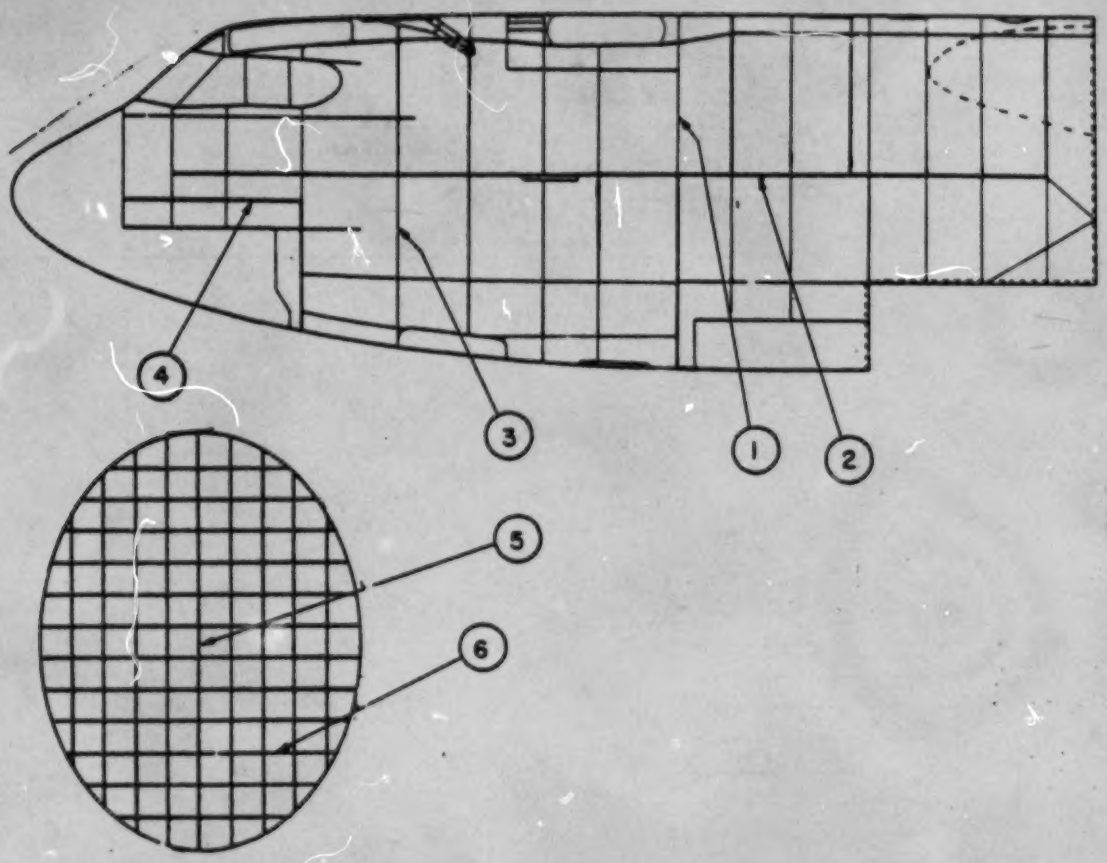
One more reference line is needed to fix the location of a unit. This line starts somewhere below the lowest part of the fuselage. Horizontal parallel lines are drawn upward from this point and numbered. The numbers tell how many inches the lines are above this lowest point. These are called Water Lines (WLs).

Circle the correct response to the following statement.

Water Lines are distances measured in inches from a point

a. parallel to the vertical centerline.
b. below the lowest part of the fuselage.
c. to the right of the vertical centerline.
d. forward of the nose.

FRAME 5



Using the above illustrations, write the designated numbers next to the correct nomenclature listed below. More than one number may be used for each nomenclature.

_____a. Body Stations (BS).

_____b. Body Buttock Lines (BBL).

_____c. Water Line (WL).

Note: If you missed any of the above questions, DO NOT GO ANY FURTHER in this text. Review frames 1 through 4 in Section II, until you understand the information and can answer the above questions correctly.

When finishing frames 1 through 5 in section II go on to Section III Frame 1.

CORRECT RESPONSES FOR SECTION II

Frame 1

a

Frame 2

1. c

2 c

Frame 3

1. F

2. F

3. T

Frame 4

b

Frame 5

a. 1 & 3

b. 5

c. 2,4,&6

SECTION III

MAJOR AIRCRAFT SYSTEMS

In this section we will cover major aircraft systems such as; propulsion, pneumatic system, fuel, pneudraulic (hydraulic), and electrical systems. These systems should be operational if an aircraft is to make a safe flight.

FRAME 2

The propulsion (engine) system provides power (thrust) to get the aircraft moving and keep it airborne.

The engine may also drive

* alternator(s)
* generator(s)
* hydraulic pump(s)

and provide pneumatic air power.

The two types of engines most commonly used on today's aircraft are the reciprocating (piston) and the jet engine.

On the response sheet place "T" for true or "F" for false for the following.

_____1. The two types of propulsion systems most commonly used on today's aircraft are reciprocating and piston.

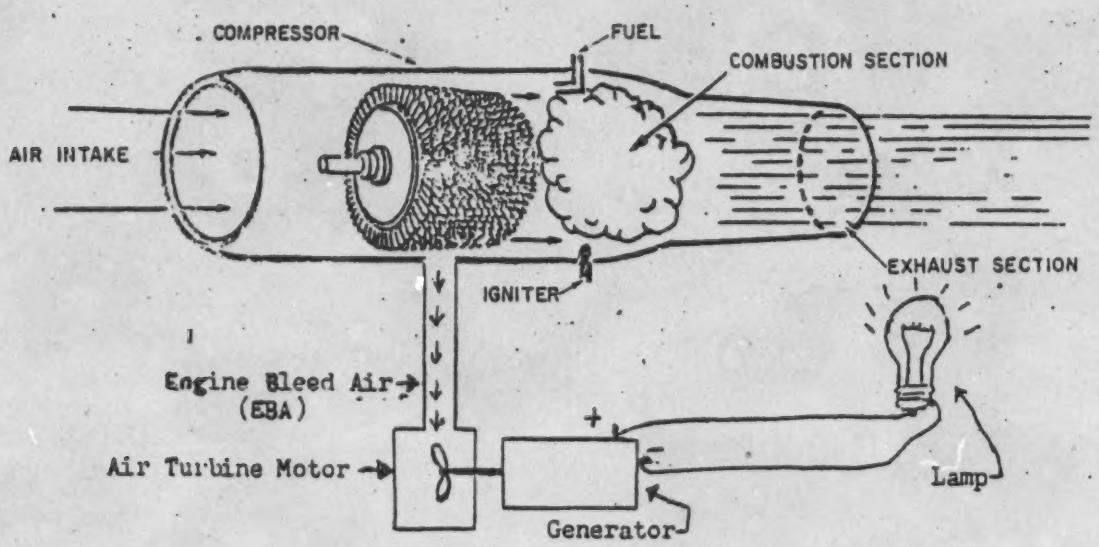
_____2. The propulsion system provides the power to get the aircraft airborne.

_____3. Alternators and generators may be driven by the engine.

Frame 3

Many military jet aircraft use a pneumatic system (air power) to drive air turbine motors to operate the hydraulic pumps, generators, alternators, and also supply air for the air conditioning system and much more.

This air comes from the compressor section in the jet engine. This compressor has two purposes, compress air for engine combustion and also to supply compressed air, or Engine Bleed Air (EBA) for the pneumatic system. EBA air comes to the pneumatic system under pressure and high temperature.



On the response sheet write the correct answer for the following.

1. The compressor in the jet engine
   a. will provide combustion for the jet engine.
   b. will provide compressed air for the engine combusion and supply EBA for air conditioning.

FRAME 4

The fuel system provides storage for large quantities of fuel and also supplies fuel to the engine(s) at the correct pressure and/or quantity. Without fuel or a fuel system, the propulsion systems (engines) are not going to operate. The fuel system may use pneumatic air from a jet engine and/or electric fuel pumps to supply fuel to the engines.

On the response sheet place "T" for true or "F" for false for the following.

_____1. The fuel systems provide the storage space for fuel and supply fuel to run the engines.

_____2. A powered aircraft can make a sustained flight without fuel or a fuel system.

_____3. Only pneumatic power is used to supply fuel to the engine(s).

Frame 5

The aircraft hydraulic (Pneudraulic) system works on the same principles as a farm, auto, or industrial hydraulic system. Just as the modern car has power steering, so have most of today's modern aircraft. The hydraulic system provides the pilot with power steering on the landing gear for maneuvering and braking on the ground. It also provides power for controlling the flight control surfaces (elevators, rudder, ailerons, etc.) while in flight.

There are many other items that depend on the hydraulic system. Some of these systems are the cargo door(s), inflight refueling boom, flight control surface(s), brake(s), etc. You will come in contact with most of these systems on the flight line.

On the response sheet write the correct answer for the following.

1. Moving flight control surface(s) is primarily done with
   a. hydraulic pressure.
   b. electricity.
2. Steering the aircraft and braking the aircraft on the ground is primarily done with
   a. hydraulic pressure.
   b. electricity.

Frame 6

Most of today's modern aircraft electrical power is alternating current (AC) and/or direct current (DC). This power can be supplied by the alternator(s), generator(s), and batteries. These sources of power supply power for the aircraft lighting, electrical, instrument(s), electronic system(s), etc.

On the response sheet write the correct answers for the following.

1. Most of today's aircraft electrical power is supplied by
   a. only DC power source(s).
   b. only AC power source(s).
   c. both AC and DC power sources.

When you have finished correctly SECTION I, II, AND III see your instructor and request the test on these three sections. If you have any questions on any part of these three sections see your instructor before you request the test.

CORRECT RESPONSES FOR SECTION III

Frame 1

No response

Frame 2

1. F
2. T
3. T

Frame 3

1. b

Frame 4

1. T
2. F
3. F

Frame 5

1. a
2. a

Frame 6

1. c

PREPARE THE MAN

Technical Training

Aircraft Environmental Systems Mechanic

PHYSICS OF SOLIDS, LIQUIDS, AND GASES

12 July 1972

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes Programmed Text 3ABR42231-PT-111, 4 January 1971.
OPR: TAM
DISTRIBUTION: X
TAM - 550; TTOC - 2

Designed For ATC Course Use

DO NOT USE ON THE JOB

FOREWORD

This programmed text was prepared for use in the 3ABR42231 instructional system. The material contained herein has been validated using forty 42010 students enrolled in the 3ABR42231 course. Ninety percent of the students taking this text surpassed the criterion called for in the approved lesson objective. The average student required 93 minutes to complete the text.

OBJECTIVES

1. Select from a list the correct atmospheric composition percentages.

2. Correctly choose statements that describe the effect altitude has on density, pressure, volume and temperature.

3. Identify areas of an illustration to show the relationship between velocity and pressure.

4. Select statements that correctly describe the relationship between volume, temperature, pressure, velocity and density.

5. Match terms with their definitions.

6. Recognize the physical difference between Fahrenheit and Celsius (centigrade) scales.

7. With no reference material - convert Celsius to Fahrenheit and Fahrenheit to Celsius. Conversion will be approximate.

8. Identify the states of matter by labeling materials with the term that applies to them.

Standard of Performance

The minimum acceptable performance will be achieved by attaining at least 70% on the criterion test.

INTRODUCTION

In this programmed text you will become acquainted with the subjects listed in the "Objectives." When you have completed the text, return to the list of objectives and see if you have accomplished them. You will be questioned on the contents of this text and you will be graded according to the extent you have achieved the objectives.

It is essential for anyone becoming an Aircraft Environmental Systems Specialist to understand some of the principles upon which our systems are designed to operate. Knowledge of certain facts will enable you to troubleshoot problems when they arise and help you develop an insight into related problems and lead you to their solutions. Please read the information presented in each small "frame," think about it, and write your answer. Check your answer on the next even numbered page. If you were incorrect, read the frame again to see what caused you to misunderstand. After you are sure of the information, move on to the next frame.

Frame 1

We find that the entire earth is composed of matter and energy. Energy will be discussed in detail in another programmed text so we will discuss only "matter." Matter is ANYTHING that HAS WEIGHT and OCCUPIES SPACE. Matter is found in three physical states, solid, liquid, or gas. You are already familiar with "solids" such as stone, iron, steel, trees, paper, and many others.

From the list below, select those things that are in their SOLID state at room temperature.

a.	water	e.	oxygen
b.	copper	f.	helium
c.	wood	g.	books
d.	iron	h.	paper

PROCEED TO FRAME 2

Frame 2

Liquid does not have a definite shape as solids do, but tends to take on the shape of the container it is in. Examples of liquids are water, gasoline, oil, etc.

From this list of materials put an "S" in front of the matter that is in its solid state and an "L" in front of those that are in the liquid state.

a.	_____ water	e.	_____ kerosene
b.	_____ wood	f.	_____ concrete
c.	_____ plastic	g.	_____ paper
d.	_____ gasoline		

PROCEED TO FRAME 3

CORRECT RESPONSE TO FRAME 1: b, c, d, g, h.

CORRECT RESPONSE TO FRAME 2: a. L, b. S, c. S, d. L, e. L, f. S, g. S.

Frame 3

Solids have a definite shape, liquids seek their own level and take on the shape of their container. GASES also assume the shape of the container in which they are confined, but they can be squeezed down to fit into a smaller container or simply allowed to float away. Examples of gaseous substances are steam, oxygen, and hydrogen. Some of these are also invisible.

In the list below, indicate the solids by placing an S in front of the materials that are solids, an L for the liquids, and a G for the items that are normally found in their gaseous state.

a.	____ sand	h.	____ water
b.	____ carbon monoxide	i.	____ salt
c.	____ gasoline	j.	____ diamonds
d.	____ milk	k.	____ air
e.	____ steam	l.	____ plywood
f.	____ cement (dry)	m.	____ oxygen
g.	____ helium	n.	____ oil

PROCEED TO FRAME 4

Frame 4

Certain terms will be used throughout this study of physics and throughout your tour as a specialist. We will familiarize you with them as we go. When we speak of matter we generally refer to an amount of matter in this manner; "the MASS of gold in a bucket is 25 lbs." Naturally we are referring to how much is in the bucket and express that quantity in terms of weight. Then, the mass of gold in the bucket is 25 lbs. (pounds). Suppose for a moment the bucket is full of oxygen. Let's say its mass is 5 lbs. If we close the bucket, compress some oxygen and stuff it into the bucket, the mass will be increased to 10 lbs or maybe more. What has happened then is this - by squeezing the oxygen we have moved the oxygen's molecules closer together so more of them will fit into the bucket. We have increased the DENSITY of the oxygen. It can be seen then that the oxygen will be heavier. Mass and Density are both measurements of quantity but the mass is expressed as weight. Another example of density is - A forest has 100 trees on one acre of ground. The forest next to it has 800 trees on one acre of ground. Which area of forest has the greatest density? The acre with 800 trees is 8 times as dense as the acre having only 100 trees. They are packed closer together.

This statement describes DENSITY very well.

"The amount of mass in a given space."

True or False?

PROCEED TO FRAME 5

Frame 5

The term "FORCE" applies to the total push or pull on matter. Example: If a tank is filled with water and that water weighs 100 lbs, it is pushing down on the bottom of the tank with a FORCE of 100 lbs. The total force on the bottom of the tank is 100 lbs.

Underline the correct answers for each of the statements below.

a. 500 lbs of cement pushes down on the earth with a total force of 500 pounds. (True) (False).

b. "Total push or pull on matter" is the definition of 1. mass, 2. density, 3. force.

PROCEED TO FRAME 6

CORRECT RESPONSES TO FRAME 3: a. S, b. G, c. L, d. L,
e. G, f. S, g. G, h. L,
i. S, j. S, k. G, l. S,
m. G, n. L.

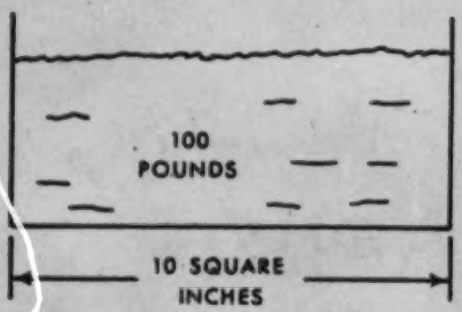
CORRECT RESPONSES TO FRAME 4: True.

CORRECT RESPONSES TO FRAME 5: True, Force.

Frame 6

PRESSURE is a term that you have heard many times. It is used when we wish to express the force applied to a given area and is measured in pounds per square inch (psi). Example: A tank having 100 lbs of water has a total force on its bottom of 100 lbs. But - if the tank's bottom area is 100 inches square, then it will have a PRESSURE of 1 pound per square inch. Since the pressure is one pound per square inch, and the bottom of the tank is 100 inches square, the total force is 100 pounds.

Refer to the illustration below and answer the questions that follow by underlining the correct answer.



a. Total (Force) (Pressure) on the bottom of the tank is 100 lbs.

b. Area of the bottom of the tank is (10 inches) (10 square inches).

c. Pressure in this tank is (100 lbs) (100 psi) (10 lbs) (10 psi) (1000 lbs) (1000 psi).

PROCEED TO FRAME 7

Frame 7

As a form of review match the terms in Column A with the definitions or statements in Column B by placing the letter of the term next to the definition or statement it matches.

Column A	Column B
a. pressure	1. _____ has a definite shape.
b. liquid	2. _____ assumes the shape of its container.
c. matter	3. _____ total push or pull on matter.
d. solid	4. _____ force applied to a given area.
e. force	5. _____ amount of mass in a given area.
f. gas	6. _____ can be compressed (squeezed down) to fit a container.
g. density	7. _____ has weight and occupies space.

PROCEED TO FRAME 8

Frame 8

You may already be acquainted with the term VELOCITY. It is commonly used when we are talking about the speed and direction of something. Example: If we are talking about how fast a bullet is traveling as it leaves the muzzle of a rifle, we call it muzzle velocity. The term velocity generally includes direction as well as speed.

Units of measurement for velocity are - miles per hour, feet per second, etc., to mention a few of the more common ones. For instance, an automobile's velocity might be 60 miles per hour.

NO RESPONSE REQUIRED

PROCEED TO FRAME 9

CORRECT RESPONSES TO FRAME 6: a. force, b. 10 sq. in., c. 10 psi.

CORRECT RESPONSES TO FRAME 7: 1. d, 2. b, 3. e, 4. a, 5. g, 6. f, 7. c.

CORRECT RESPONSES TO FRAME 8. NONE REQUIRED

Frame 9

Humidity is a word nearly everyone has heard. We use it when we refer to the moisture in the air. You will hear it often as you continue through this career field.

Write the correct term in the space beside its definition. Terms are in the left column and definitions in the right column.

Humidity	a. _____	can be compressed.
Velocity	b. _____	has a definite shape.
Density	c. _____	speed and direction of an object.
Solid	d. _____	has weight and occupies space.
Liquid	e. _____	moisture in the air.
Gas	f. _____	amount of mass in a given space.
Matter	g. _____	assumes the shape of its container.

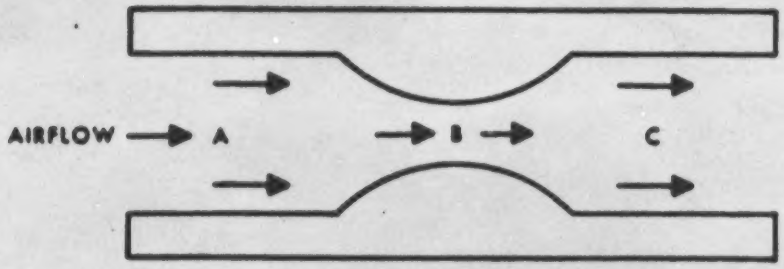
PROCEED TO FRAME 10

Answers to Frame 9:

a. gas
b. solid
c. velocity
d. matter
e. humidity
f. density
g. liquid

Now that you are familiar with some of the terms used in our career field, we will go on to some of the subjects with which they are associated. So you will see what happens to a gas (air for example) as it passes through pipes in our systems, we have drawn an illustration below that shows the relationship between pressure and velocity. As you study the illustration, keep this fact in mind -

IF THE SAME AMOUNT OF AIR LEAVES A PIPE AS ENTERS IT, PRESSURE WILL BE GREATEST WHERE THE DIAMETER IS LARGEST AND VELOCITY WILL BE GREATEST WHERE THE DIAMETER IS SMALLEST. Look at the illustration as we explain this. Notice the diameter of Point A is the same as the diameter of Point C. If at Point A the Velocity is 100 mph it will also be 100 mph at Point C. BUT it will be much higher (say 500 mph) at Point B. Pressure at Points A and C is 100 psi but at Point B is only 20 psi.



As proof of this "pressure-velocity" relationship hold a piece of paper as shown below and blow a high speed stream of air across the top of the paper.

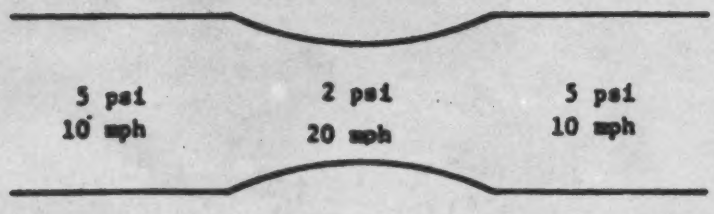
Notice that as the velocity of air increases the paper moves upward toward it! Does this look like the pressure is high where the velocity is high? NO - instead a low pressure area occurs where the velocity is high and because the pressure below the paper is high (and the velocity is zero), the high pressure air below rushes up toward the low pressure area above the paper pushing the paper UP with it.

NO RESPONSE REQUIRED

PROCEED TO FRAME 11

Frame 11

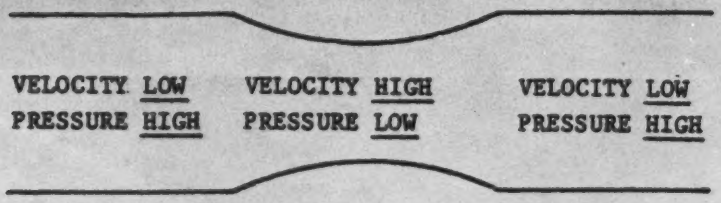
Notice that in the illustrations below we have made a comparison between the pressures and velocities.



The pressure drops as the velocity of the air increases as it rushes through the narrow part of the pipe.

Think of a squadron of airmen in formation ALL trying to get through a door at the same time. IF as many get through the door as enter it without anyone stopping, some one is going to have to run through that door. The velocity (speed) has increased. The key here is that as many leave as enter. In the illustration below write the word "High" or "Low" next to the terms Velocity and Pressure according to what it should be at that point.

//////////////////////////



Frame 12

Since our systems deal largely with air and its velocity, temperature, density, volume, and pressure, we will look into the relationship between them. Changing one of them has some effect on the others.

If a tank is filled with air (a gas), the cap is placed on, and then the tank is squeezed down to where its volume (volume is how much it can normally hold) becomes much less, what will happen?

Right - the density of the air increases inside, that is, all of the air molecules are squeezed closer together so that as they move around more and more of them strike the walls of the tank. As more of them strike the tank the force inside becomes greater and greater until finally - POW, the tank explodes or pops its seams.

Underline the correct answers to the questions or statements below.

a. If the volume of a tank is decreased, the pressure inside will (increase) (decrease).

b. The molecules of the air are squeezed together if the volume of the tank is decreased. (True) (False).

PROCEED TO FRAME 23

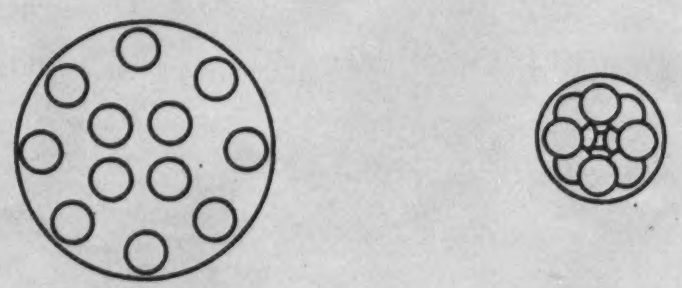
CORRECT RESPONSES TO FRAME 12: a. increase, b. true.

Frame 13

Have you noticed how HOT a compressor becomes as the air is compressed and forced into the storage tank? If the air is compressed, the density increases. All of the molecules of air are squeezed closer together and more of them strike the wall of the tank. They also get hot from rubbing against each other and the inside wall of the tank. These things happen then if a gas (air) is compressed.

The pressure increases.
The temperature increases.
The density increases.

See the difference between these two drawings.



There are 12 molecules of gas in each of these two containers, but something has happened.

Underline the correct word in the statements below.

a. Tank A has the (greater) (smaller) VOLUME.

b. Tank A has the (greater) (least) DENSITY.

c. Tank B has the (higher) (lower) TEMPERATURE.

d. Tank B has the (greatest) (least) PRESSURE.

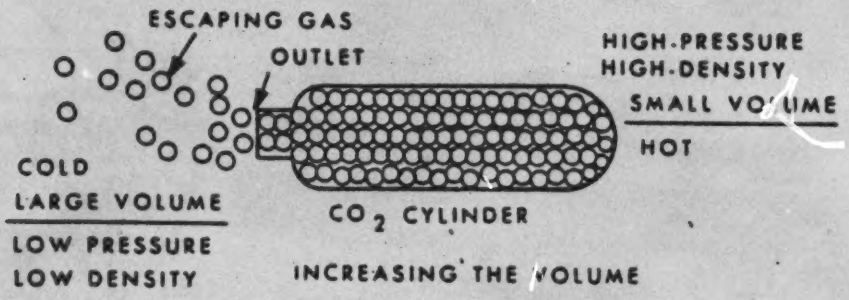
e. The walls of tank "B" are being struck by the gas molecules (most often) (least often).

f. Friction between the molecules will be greater in tank (A) (B).

PROCEED TO FRAME 14

Looking at it a little differently, we can see that if instead of compressing the gas we EXPAND it, some interesting things happen. Have you ever seen a small CO_2 cartridge fired? Like the ones used in model boats, racers, or airplanes. Remember how the cylinder FROSTED over?

As the volume expanded, the gas came from a small volume in the cylinder to a large volume (the outside air around the cylinder), the molecules moved far apart. The density of the gas has decreased is another way of saying it. The pressure and temperature have dropped at the outlet of the cylinder. Low pressure, cold temperature!



From this example underline the correct words in the statements that follow.

As the volume of a gas increases OUTSIDE of the container:

a. the density (increases) (decreases).

b. the temperature (increases) (decreases).

c. the pressure (increases) (decreases).

d. the gas is being (compressed) (expanded).

PROCEED TO FRAME 15

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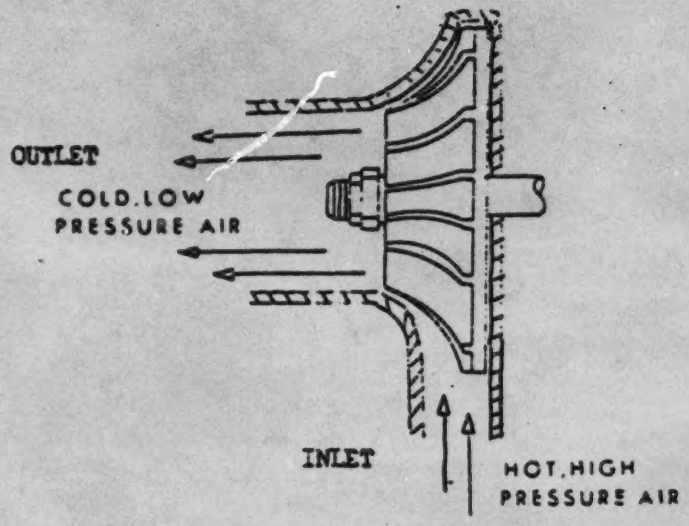
CORRECT RESPONSES TO FRAME 13: a. greater, b. least, c. higher, d. greatest, e. most often, f. B.

CORRECT RESPONSES TO FRAME 14: a. decreases, b. decreases, c. decreases, d. expanded.

Frame 15

Below is an illustration of a "cooling turbine." Notice how it resembles the agitator in a washing machine or a water pump impeller in a car.



High-pressure, high-temperature air is blown from a pipe onto the large end of the turbine where the turbine then EXPANDS the air by rapidly spinning it outward at a tremendous rate.

Remember what you already know about air that has been expanded?

Underline the correct word in each statement below. You may refer to the illustration of the turbine if you wish.

a. The hottest air is at the (inlet) (outlet) end of the turbine.

b. The lowest pressure will be found at the (inlet) (outlet) end of the turbine.

c. The purpose of this turbine is to (compress) (expand) the air.

d. Air is expanded to (cool) (heat) it.

e. Air that is spun out from the outlet end of the turbine is (high-pressure, high-temperature) (low-pressure, low-temperature).

f. This device might properly be called a (cooling turbine) (compressor).

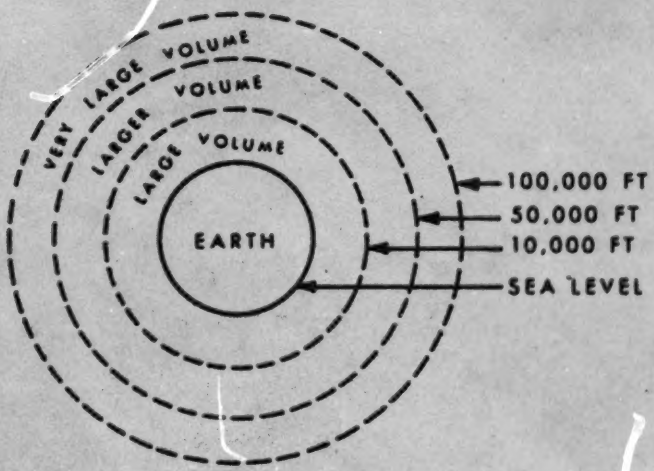
PROCEED TO FRAME 16

You have seen that changing either temperature, pressure, volume, density, or velocity will have some effect on all the others.

Each of these must be taken into consideration when an air-conditioning system is designed or when something goes wrong and you are required to locate the trouble.

To do this you must extend your thinking to include the effect higher or changing altitudes will have on these principles. This will be easy to understand since you already are familiar with the principles involved.

In the following frames you will see how temperature, density, pressure, and volume vary at different altitudes where aircraft operate.



The Volume of the earth's atmosphere is largest at the highest altitude.

PROCEED TO FRAME 17

330

CORRECT RESPONSES TO FRAME 15: a. inlet, b. outlet, c. expand, d. cool, e. low-pressure, low-temperature, f. cooling turbine.

CORRECT RESPONSES TO FRAME 16: NONE REQUIRED.

Frame 17

At sea level the air presses on our body with a pressure of 14.69, or 14.7 pounds per square inch. This is normal at sea level but what happens if we go to a higher altitude? Is it the same as at sea level?

The table illustrated below will show you changes that occur at different altitudes. Refer to the table to get the figures you will need to complete the statements that follow. Underline the correct answer wherever it is required.

Table of U. S. Standard Atmosphere

ALTITUDE	PRESSURE		TEMPERATURE		DENSITY RATIO
Feet	Mm of Hg	Lb per sq in	C	F	
0	760.0	14.69	15.0	59.0	1.000
2000	706.8	13.67	11.0	51.9	.9428
4000	656.3	12.69	7.1	44.7	.8881
6000	609.0	11.78	3.1	37.6	.8358
8000	564.4	10.91	- 0.8	30.5	.7859
10000	522.6	10.11	- 4.8	23.3	.7384
12000	483.3	9.35	- 8.8	16.2	.6931
14000	446.4	8.63	-12.7	9.1	.6499
16000	411.8	7.96	-16.7	1.9	.6088
18000	379.4	7.34	-20.7	- 5.3	.5698
20000	349.1	6.75	-24.6	-12.3	.5327
22000	320.8	6.20	-28.6	-19.5	.4947
24000	294.4	5.69	-32.5	-26.6	.4640
26000	269.8	5.22	-36.5	-33.7	.4323
28000	246.9	4.77	-40.5	-40.9	.4023
30000	225.6	4.36	-44.4	-48.0	.3740
32000	205.8	3.98	-48.4	-55.1	.3472
34000	187.4	3.62	-52.4	-62.3	.3218
35332	175.9	3.41	-55.0	-67.0	.3058
36000	170.4	3.30	-55.0	-67.0	.2962
38000	154.9	3.00	-55.0	-67.0	.2692
40000	140.7	2.72	-55.0	-67.0	.2447
42000	127.9	2.47	-55.0	-67.0	.2224
44000	116.3	2.25	-55.0	-67.0	.2021
46000	105.7	2.04	-55.0	-67.0	.1838
48000	96.05	1.86	-55.0	-67.0	.1670
50000	87.30	1.69	-55.0	-67.0	.1518
52000	79.34	1.53	-55.0	-67.0	.1379
54000	72.12	1.39	-55.0	-67.0	.1254
56000	65.55	1.27	-55.0	-67.0	.1140
58000	59.58	1.15	-55.0	-67.0	.1036
60000	54.15	1.05	-55.0	-67.0	.0941

a. At sea level (0-feet) atmospheric pressure is _____ lb per sq in (psi).

b. At 18,000 ft, pressure is _____ psi.

c. Atmospheric pressure at 18,000 ft is approximately (1/2) (1/4) (two times) as much as it is at sea level.

d. Atmospheric pressure at 60,000 ft is _____ psi which is about (1/2) (1/15) (two times) (15 times) as much as it is at sea level.

e. The temperature at 30,000 ft is (hotter) (colder) than it is at sea level.

f. The temperature is approximately 0°F at approximately _____ feet.

g. The temperature stays the same from _____ feet to _____ feet.

h. Density ratio of the air is _____ at sea level.

i. An air density ratio of .5327 is equal to _____ feet.

j. At _____ feet the air density is only 1/4 (approx) or .2447 as much as it is at sea level.

k. The air is (more) (less) dense at 60,000 feet than it is at sea level.

l. Atmospheric pressure is (greater) (less) at 60,000 feet than it is at sea level.

m. Temperature at 60,000 feet is (hotter) (colder) than it is at sea level.

n. VOLUME of the atmosphere at high altitude is (greater) (less) than it is at sea level.

PROCEED TO FRAME 18

Frame 18

Going back for a moment we can see that a gas is affected by any change in temperature, volume, density and pressure. Now we can compare those very same effects to the effect changing altitudes will have on a gas, such as the atmosphere around us. Did you see that as we increase altitude the VOLUME of the earth's atmosphere increases? Whenever the VOLUME increases, the pressure decreases.

Underline the correct answer to the questions below.

a. At high altitude the VOLUME of the earth's atmosphere (increases) (decreases).

b. The VOLUME of the earth's atmosphere is least at (60,000 feet) (sea level).

PROCEED TO FRAME 19

CORRECT RESPONSES TO FRAME 17: a. 14.69, b. 7.34, c. 1/2, d. 1.05 and 1/15, e. colder, f. 16,000 (Approx), g. 35, 332 to 60,000, h. 2.000, i. 20,000, j. 40,000, k. less, l. less, m. colder, n. greater.

CORRECT RESPONSES TO FRAME 18: a. increases, b. sea level.

Frame 19

If the volume increases the pressure will be less. The same is true at high altitude. The volume of the atmosphere is much larger, the molecules of air move further apart (become less DENSE) and as a result the PRESSURE decreases.

You may recall that when the pressure drops the TEMPERATURE also decreases. The air molecules have moved further apart and there is less friction between them to heat them.

Let's see if you have these few facts straight. In the chart below underline the word that describes the conditions at the altitude shown by comparing the two altitudes.

	Sea Level	50,000 Feet
Temperature	(high) (low)	(high) (low)
Pressure	(high) (low)	(high) (low)
Density	(high) (low)	(high) (low)
Volume	(small) (great)	(small) (great)

PROCEED TO FRAME 20

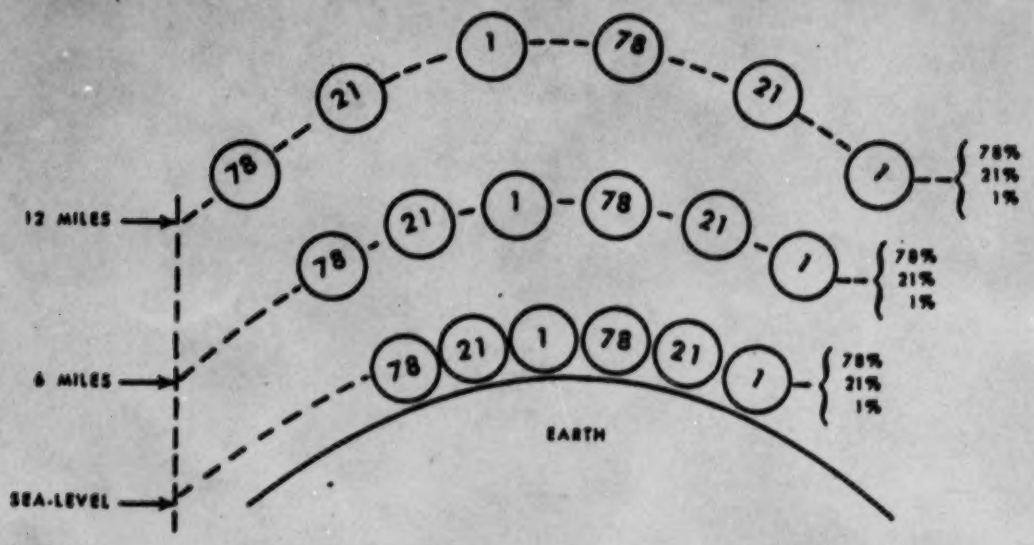
Frame 20

The earth's atmosphere is actually a sea of gases that surround the earth. This "gas" is made up of several different gases, one of which we depend upon for life support. This gas is oxygen. Nearly everyone knows that without oxygen to breathe, human life would be snuffed out in just a few short minutes.

The sea of gas surrounding us is composed (made up) of nitrogen, oxygen, and other gases in the following percentages . . . . . .

Nitrogen	78%
Oxygen	21%
Other gases	1%

While oxygen makes up only 21% of the atmosphere there is certainly enough for everyone at sea level. But how about at high altitudes? There's the same 21% at high altitudes with just one very important difference - DENSITY. Remember, the higher you go, the less dense the atmosphere is. (Refer to Frame 19.)



If you drink from a glass of kool aid that is made up of 98% water and 2% kool aid, you can drink it all down in a few swallows because the molecules in the glass are very dense. Now, spill the same glass of 98% water and 2% kool aid into a large shallow pan. Can you get it all up in a few swallows or will you have to move around to get it all up?

You see - the percentage is the same but the density (amount in a given area) has decreased. This is exactly the same for the atmosphere, the same percentage of nitrogen - 78%, oxygen - 21%, and other gases - 1% is at all altitudes but because the molecules are so far apart at high altitude you will not get as many with each breath.

Underline the correct answers to the statements below:

a. The percentage of gases in the earth's atmosphere is 78% nitrogen, 21% oxygen, and 1% other gases. (true) (false)

b. There is as much oxygen in a gallon of air scooped up at high altitude as there is in a gallon of air taken at sea level. (true) (false)

c. At 60,000 feet the atmosphere contains (21%) (78%) (91%) oxygen.

d. At 35,000 feet there is (21%) (78%) nitrogen.

PROCEED TO FRAME 21

334

CORRECT RESPONSES TO FRAME 19: high, high, high, small, low, low, low, great.

CORRECT RESPONSES TO FRAME 20: a. true. b. false (less dense at high altitude) c. 21% d. 78%

Frame 21

Humidity in the atmosphere is something we pay little attention to, but as an Environmental System specialist you'll find humidity can be a problem. Early in this program you learned humidity was the "moisture in the air." We will add at this point that we are concerned only with the humidity below 35,000 feet because above that altitude there isn't enough to worry about. The air can contain a certain amount of water vapor depending on the air temperature.

You have seen water form droplets on the outside of a glass of cold water on a hot day. As soon as the "moisture" in the hot air is cooled by the cold sides of the water glass, it turns from a gas back to a liquid.

What we have said then is that if the atmosphere is "cooled" the moisture (humidity) will turn to a liquid, or in this case, RAIN.

Underline the correct answers to the statements below.

a. Moisture in the air is called (dampness) (humidity).

b. Moisture is only found <u>above</u> 35,000 feet. (true) (false)

c. Droplets will form on the outside of a glass of (hot) (cold) water if the air around it is warm.

d. We can expect to find rain above 35,000 feet. (true) (false)

e. Usually we can expect rain if the temperature drops quickly on a hot day. (true) (false)

PROCEED TO FRAME 22

Rain falls because the water vapor is cooled until it becomes a liquid. Liquid is heavier than air so the moisture falls in the form of rain. Since the air above 35,000 feet is very cold (see the chart in Frame 17) it cannot hold moisture. In fact the moisture will have cooled and fallen as rain before it ever gets to 35,000 feet.

NO RESPONSE REQUIRED, PROCEED TO FRAME 23

Frame 23

On some occasions in the future you may be required to use a temperature scale that is different than the Fahrenheit scale you are accustomed to. There is really no difference in scales insofar as physical size is concerned. It is how many lines the scales are divided into that makes the difference.

In figure A we see two thermometers that have been heated the same amount. Notice that the mercury has risen the same amount in each.

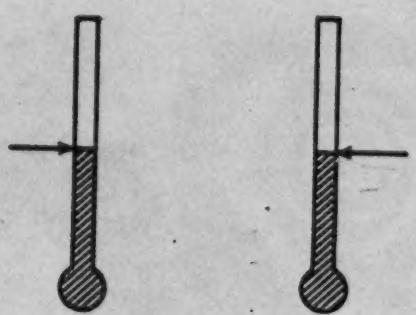
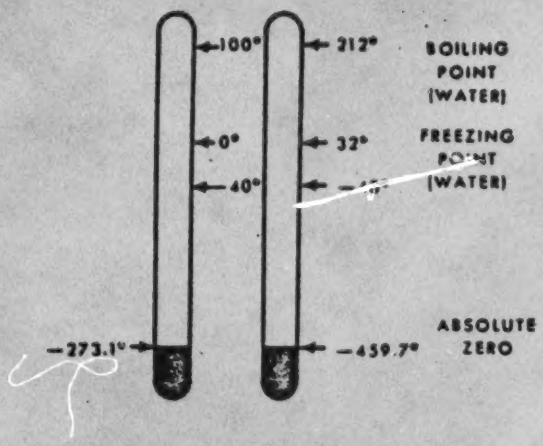


FIGURE A

Responses to frame 21: a. humidity, b. false, c. cold, d. false, e. true.

336



Frame 24

The two actual scales we will work with are the Fahrenheit scale (you already know this one) and the Celsius scale. The Celsius scale was previously called the Centigrade scale. CENTI GRADE - because it is "graded" in hundredths. This illustration shows both of the scales. If we compare these two scales to see how much difference there is between the markings on them we will find there is 180° on the Fahrenheit scale for 100° on the Celsius scale. An explanation of this follows.

Look at the Celsius scale. The freezing point of water is 0°, while on the Fahrenheit scale the freezing point of water is 32°. If you look for the boiling point of water (at sea level) you will find it is 100° Celsius and 212° Fahrenheit. Perhaps you noticed there are 100° Between freezing and boiling on the Celsius scale, that is 0°to 100° = 100° and between 32° and 212° on the Fahrenheit scale there are 180° or 212.

$$\begin{array}{r} -32 \\ \hline 180 \end{array}$$

Since the actual difference is 100° and 180° we can make it easier to remember the difference by breaking it down this way.....

100 - 180
10 - 18
1.0 - 1.8 or for each degree Celsius there are 1.8 degrees Fahrenheit. 1.8 is <u>almost</u> two degrees so it becomes easy to remember that the Fahrenheit scale is nearly twice as large as the Celsius scale. <u>There is one thing that must</u> be remembered -- the Fahrenheit scale STARTS AT 32° (using the freezing point of water as a starting point) so we must allow for this.

You may look at the two scales to answer these questions by underlining the correct answer or filling in the blanks.

a. The scale having the <u>most</u> graduations is the _____ scale.

b. The lowest mark on the Celsius scale is _____° below zero.

CORRECT RESPONSES TO FRAME 23: a. No 1, b. 18, c. 180, d. True.

CORRECT RESPONSES TO FRAME 24: a. Fahrenheit, b, 273.1° below c, 100, 212, d. 180, e. false.

---

c. Water boils at _____ degrees Celsius and _____ degrees Fahrenheit.

d. There are _____ degrees difference between the freezing points and boiling points of the Fahrenheit scale.

e. The same amount of heat will make the mercury climb higher in one thermometer tube than in the other. (true) (false)

PROCEED TO FRAME 25

Frame 25

Zero on the Fahrenheit scale is 32° less than the freezing point of water so we will have to allow for that difference when we convert from one scale to the other. To change a Celsius reading to a Fahrenheit reading it must be remembered the Fahrenheit number will come out larger than the Centigrade number. This is a clue to solving the problem. To make a small number <u>larger</u> you can multiply and add. Let's try one.

Change 25°C to Fahrenheit.

First step - <u>Multiply</u> 25°C by 1.8. (Remember the Fahrenheit scale has 1.8 degrees for every degree Celsius.)

$$\begin{array}{rr} & 25 \\ \times & 1.8 \\ \hline & 200 \\ = & 25 \\ \hline & 45.0 \end{array}$$

Second step - <u>Add</u>

$$\begin{array}{rr} & 45.0 \\ + & 32.0 \text{ (explained above)} \\ = & 77.0^\circ \text{ Fahrenheit} \end{array}$$

Therefore, 25°C = 77°F.

Just two easy steps. Solve the problems below by changing the Celsius Readings to Fahrenheit readings.

Write your answers on this page.

a. 26°C = _____°F

b. 30°C = _____°F

c. 10°C = _____°F

d. 5°C = _____°F

e. 15°C = _____°F

f. 40°C = _____°F

PROCEED TO FRAME 26

Frame 26

Did you multiply and add in each case? If so, you probably had no trouble arriving at the correct answer each time. It is just as easy to convert Fahrenheit scales to Celsius scales (a large scale to a smaller scale) by SUBTRACTING and DIVIDING. Follow through these easy steps to see how it is done. Change 78.8°F to Celsius.

First step - Subtract

$$\begin{array}{r} 78.8^{\circ}F \\ -32. \\ \hline 46.8 \end{array}$$

(Don't forget the 32)

Second step - Divide

$$1.8 \overline{)\,46.8}\quad 26.0$$

$$\begin{array}{r} 36 \\ \hline 108 \\ 108 \\ \hline 000 \end{array}$$

Answer - $78.8^{\circ}F = 26.0^{\circ}C$

Again, two easy steps, only this time to change a large scale to a small scale we SUBTRACT and then DIVIDE. Now solve a few to see how well you have learned to convert from one scale to the other. Write your answers in the spaces provided.

a. $95^{\circ}F =$ _____ $^{\circ}C$

b. $140^{\circ}F =$ _____ $^{\circ}C$

c. $70^{\circ}F =$ _____ $^{\circ}C$

d. $50^{\circ}F =$ _____ $^{\circ}C$

e. $60^{\circ}F =$ _____ $^{\circ}C$

f. $100^{\circ}F =$ _____ $^{\circ}C$

PROCEED TO FRAME 27

Frame 27

If you are honestly doing well at converting from one scale to the other you will enjoy solving the problems we have presented below. If you are a little shaky though, we would rather you go back far enough to reassure yourself and then return to solve these problems.

Using the correct procedure, convert these temperatures. Write your answer in the spaces provided and remember - large to small - subtract then divide, small to large - multiply then add.

a. $50^{\circ}C =$ _____ $^{\circ}F$

b. $60^{\circ}C =$ _____ $^{\circ}F$

c. $70^{\circ}C =$ _____ $^{\circ}F$

d. $90^{\circ}F =$ _____ $^{\circ}C$

e. $80^{\circ}F =$ _____ $^{\circ}C$

f. $115^{\circ}F =$ _____ $^{\circ}C$

PROCEED TO FRAME 28

CORRECT RESPONSES TO FRAME 25: a. 78.8°F, b. 86.0°F, c. 50.0°F,
d. 41.0°F, e. 59.0°F, f. 104.0°F

CORRECT RESPONSES TO FRAME 26: a. 35.0°C, b. 60.0°C, c. 21.1°C,
d. 10.0°C, e. 15.6°C, f. 37.8°C.

CORRECT RESPONSES TO FRAME 27: a. 122.0°F, b. 140.0°F, c. 158.0°F,
d. 32.2°C, e. 26.7°C, f. 46.1°C

Frame 28

If you are one of the specialists who may someday have a chance to go to Europe you will find a daily use for temperature conversion. Suppose someone casually says to you, "It must be about 20° Celsius today." Now you're on the spot, how will you answer? There is a simple solution to this dilemma. Try this, to change a small (Centigrade) scale to a large (Fahrenheit) scale, you must MULTIPLY and then ADD. It's difficult to multiply by 1.8 in your head but easy to multiply by 2. Try it --- Someone said it's 20°C today.

Quickly now, 2 x 20 = 40 + 32 = 72°F. Was that hard? 20°C = 72°F. Let's check it. 20°C = °C x 1.8 + 32 = 68°F. Not bad, in fact 72° is close enough to 68° for conversational purposes. Of course, it would be just as easy to tell that Fraulein, "it's a nice cool 10° Celsius, isn't it? How did you do it? You know it was 52°F and that to make a large (°F) scale small (°C) you SUBTRACT and then DIVIDE. Try it. Subtract 32 from 52, you have 52

$$\underline{-32}$$
$$=20$$

then

then divide by 2 $2\overline{)20}$ $\quad 10$

the temperature is 10° Celsius and you look like a genius. How close was your approximation? Check it - (when you divide, watch the decimal point carefully).

$$°C = \frac{°F - 32}{1.8} = \frac{52}{\underline{-32}} \qquad 1.8\overline{)20.0} \quad 11.1$$
$$20$$

The accurate answer is 52°F = 11.1°C. That was close, only 1 degree off.

Convert these in your head.

a. 62°F = _____°C

b. 44°F = _____°C

c. 32°F = _____°C

d. 5°C = _____°F

e. 20°C = _____°F

f. 1°C = _____°F

PROCEED TO FRAME 29

Frame 29

Why did we go to the trouble of showing you a way to do it in your head? It provides you with a means of remembering the PROPER PROCEDURE for temperature scale conversion and as a rough check of your own work to see if you have overlooked any of the steps. Here is an example of how you might use it. Sgt. Jones was in a hurry, and using a pencil, he quickly changed 102°F to 51°C.

In your head check his figures to see if he used the proper procedure.

a. The approximate answer should be 35°C. (True) (False)

b. Did he arrive at the correct estimate? (Yes) (No)

c. He should have subtracted 32 and then divided the answer by 2. (True) (False)

d. Using a pencil determine the EXACT answer. The EXACT answer is (35°C) (38.8°C) (51.0°C)

PROCEED TO FRAME 30

Frame 30

Check your responses for Frames 28 and 29 on page 26.

This concludes this portion of physics. If you have any further questions or comments, please bring them to the instructor's attention. He will guide you to the next unit of instruction.

CORRECT RESPONSES TO FRAME 28: a. 15°C, b. 6°C, c. 0°C, d. 42°F, e. 72°F, f. 34°F.

CORRECT RESPONSES TO FRAME 29: a. True, b. No, c. True, d. 38.8°C.

PROGRAMMED TEXT
3ABR42331-PT- 107

Technical Training

Aircraft Environmental Systems Mechanic

ELECTRON THEORY

18 March 1977

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
3370th Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE
DO NOT USE ON THE JOB

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FOREWORD

This programmed text was prepared for use in the 3ABR42331 instructional system. The material contained herein has been validated using 30 students enrolled in the 3ABR42331 course. Ninety percent of the students taking this text surpassed the criterion called for in the approved lesson objective. The average student required three hours to complete the text.

OBJECTIVES

Without reference, relate electrical characteristics of materials to the flow of electrical current, and also select the result that would occur from a change in temperature of materials with a minimum of 80% accuracy.

INTRODUCTION

Some of the information that you will study in this PT is background information. Once having mastered the subject matter, you will understand why an electrical current (a flow of electrons) occurs. Understanding how and why current flows will aid you in understanding how electron tubes, solid state devices, and other electronic equipment works.

INSTRUCTIONS

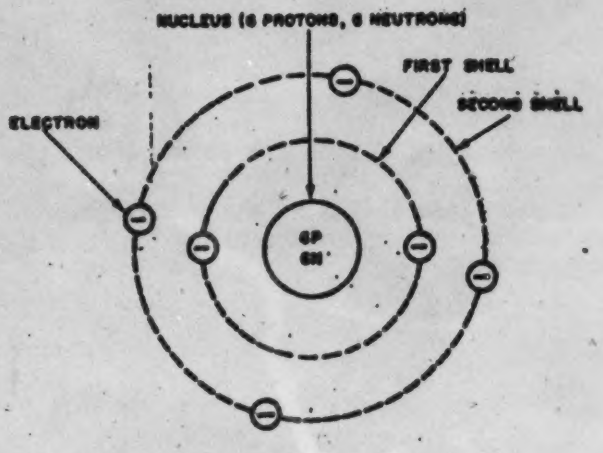
This programmed text presents information in small steps called "frames". Read the material presented, select your response(s) at the end of the frame as required. Do not mark in the text. Enter your response(s) on the response sheet provided. After you have made your selections check your work against the answers on the following page. If the responses are not provided ask your instructor to grade it. If your selections were correct, go on to the next frame and repeat the above process. If you have made an incorrect response, reread the frame until you understand your error and/or see your instructor.

OPR: 3370TTG
DISTRIBUTION: X
3370TTGTC - 200; TTVSR - 1

Answers to Frame 1: 1. T 2. T 3. _ 4. M 5. M 6. E 7. M
8. M 9. E 10. M 11. E 12. E

Frame 2

As we stated in the last frame, the atoms that make up one type of material are very different from the atoms that make up other kinds of materials. These atoms vary in the number of subatomic particles or very small bits that they contain. There are three main subatomic particles which are called PROTONS, NEUTRONS, and ELECTRONS. Of the three, the electron is the most important to you in working with electricity. In the figure shown of the carbon atom, you can see just how the subatomic particles relate to the atom. The protons and neutrons together make up the center or NUCLEUS of the atom, around which the electrons revolve, much like our planet revolves around the sun. The electron is very small and is said to have a very small negative charge of electricity. The proton in the center is said to have a positive charge of electricity. This positive charge is equal in strength but opposite to the charge of the electron.



CARBON ATOM

Mark the following true statements with a "T" on your response sheet.

_____ 1. The electron is considered to have a small negative charge.

_____ 2. The carbon atom pictured above has the same number of electrons as protons.

_____ 3. Electrons revolve around the nucleus of an atom.

_____ 4. The proton is considered to have no electrical charge.

Our earth and atmosphere is made up of matter and energy. Matter is defined as things that take up space and have weight. Bricks, trees, people, air, paper, milk, wire, steel and water are only a few examples of matter. They all have weight and take up space. Matter can be in three states: solids, liquids, and gases. All matter is made up of small particles called atoms. Atoms which make up one body of material are different from atoms which make up other kinds of materials. But what of those things that do exist and yet do not have weight nor take up space?

For instance: heat, light, sound and electricity. None of these can be weighed. Have you ever seen a tin can full of light? These are forms of energy. Energy is the ability to do work.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on your response sheet.

_____ 1. This P T is an example of matter.

_____ 2. This PT is made up of small particles called atoms.

_____ 3. An atom of silver is identical to an atom of gold.

Next to each item listed in the columns below, write the letter "E" for energy or the letter "M" for matter that correctly describes which it is:

____4. glass

____5. water

____6. electricity

____7. sand

____8. oxygen

____9. light

____10. gasoline

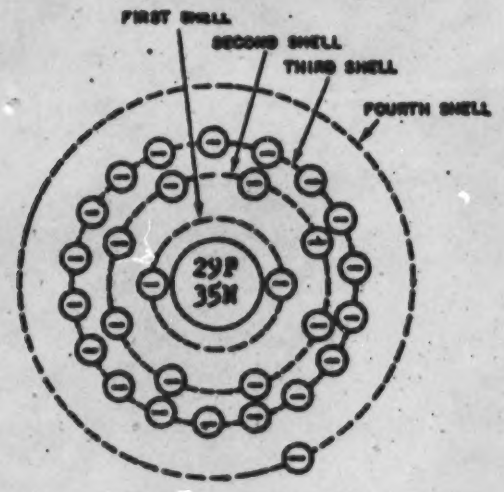
____11. heat

____12. sound

Answers to Frame 2: 1. T 2. T 3. T 4. _

Frame 3

In most atoms there is a small part with no charge, called a neutron. This small neutron has a mass just about the same size as a proton but will not have an electrical charge. The protons and neutrons make up a very heavy center or nucleus around which the very light electrons revolve. As the atom becomes more and more complicated, the number of protons and electrons will also increase in number. But, not all of the electrons revolve in the same belt, orbital path or shell as shown in the figure below. The maximum number of electrons that any one belt or shell may have is limited. lectrons in the inside belts or shells, are bound tightly to the nucleus or center of the atom. The electrons in the outer shells are not as tightly bound to the nucleus and when an outside force is applied, the electrons in the outermost shell may be freed from the atom.



COPPER ATOM

Mark the following true statements with a "T" on your response sheet.

_____ 1. Electrons in the outer shells of an atom are easily removed.

_____ 2. The neutron has no electrical charge.

_____ 3. The copper atom shown in this frame has one electron in its outer orbit.

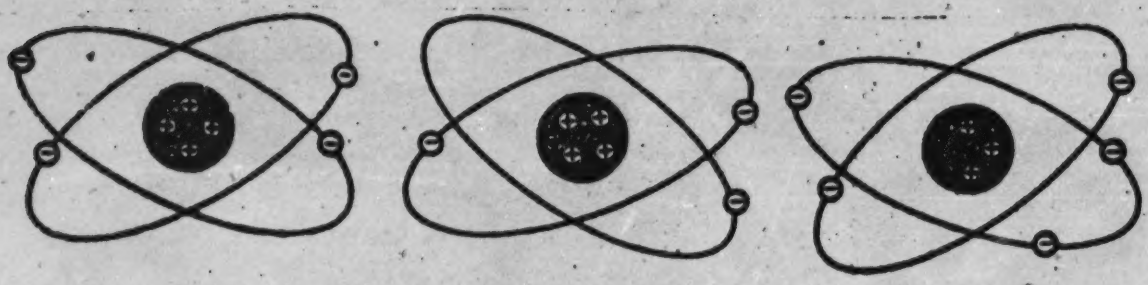
_____ 4. The protons and neutrons together make up an ion.

DO NOT MARK IN THIS TEXT

Answers to Frame 3: 1. T 2. T 3. T 4. _

Frame 4

Under normal conditions an atom is electrically neutral, that is, the number of protons is equal to the number of electrons. See figure A. If an atom is not neutral, it is called an ion. For an atom to become an ion it must either lose or gain an electron. If one electron is torn away from the atom as shown in figure B, this will leave the atom with a deficiency of electrons. Thus, this atom has more positive charges than negative charges. This atom is then referred to as a positive ion. In figure C below, this atom has gained an extra electron. This makes it more negatively charged than a neutral atom so it is referred to as a negative ion.



A. BALANCED ATOM

B. UNBALANCED ATOM

C. UNBALANCED ATOM

DO NOT MARK IN THIS TEXT

Mark the correct answer for each of the following questions on the response sheet.

_____ 1. An atom with six electrons and five protons is a

a. negative ion.
b. positive ion.

_____ 2. An atom with six electrons and six protons is a

a. unbalanced atom.
b. balanced atom.

_____ 3. Under certain conditions electrons in the outer orbit can be forced to leave an atom.

a. True
b. False

_____ 4. An atom with eight electrons and nine protons is a

a. negative ion.
b. positive ion.

Answers to Frame 4: 1. a 2. b 3. a 4. b

Frame 5

DO NOT MARK IN THIS TEXT

Match the terms on the right to their descriptions on the left by placing the correct letter in each blank on your response sheet.

NOTE: Each letter may be used more than once.

_____ 1.	Negatively charged.	a. Neutrons
_____ 2.	Positively charged.	b. Protons
_____ 3.	No electrical charge.	c. Electrons
_____ 4.	Revolves around the nucleus.	
_____ 5.	Has mass approximately equal to that of a proton.	
_____ 6.	Together with the neutrons make up the nucleus of the atom.	

Mark the following true statements with a "T" on your response sheet.

_____ 7. A negative ion has more electrons than protons.

_____ 8. Normally an atom has the same number of electrons as protons.

_____ 9. An atom that has gained an electron would be called a positive ion.

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Answers to Frame 5: 1. c 2. b 3. a 4. c 5. a 6. b

7. T 8. T 9. _

Frame 6

As was stated in past frames an atom can be made to lose or gain electrons under man-made conditions. The electrons which move from one atom to another are kind of loosely bound to the nucleus. These electrons are referred to as valence electrons. These are the ones that are easiest to take from an atoms outer shell. Maybe now you are wondering where the "lost" electrons go, and where the gained electrons come from. We know that when they go some place or come from some place, there has to be movement involved. This movement of the electrons is defined as current flow, and will be discussed later in this lesson. These electrons that are loosely bound to the nucleus of an atom are referred to as FREE electrons. They are not exactly free, but they will tend to move from one atom to another, exchanging places all the time with other free electrons.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on your response sheet.

_____ 1. Electrons in the outer orbit are the ones most easily removed from an atom.

_____ 2. The electrons that are loosely bound to the nucleus are called free electrons.

Answers to Frame 6: 1. T 2. T

Frame 7

A good conductor is a material that has atoms which have a large number of free electrons. Some good examples of conductors are silver, gold, copper, and aluminum. Silver is a much better conductor than copper, but you will find copper used more often, because it does not cost as much. It is stronger than silver and is very easy to bend and form. Aluminum is light and is used when weight is an important factor. An insulator is a material whose atoms have very few free electrons. No known material is a perfect insulator. Some materials are such poor conductors, that for all practical use, they are rated as insulators. Some examples are glass, dry wood, rubber, mica, and some plastics.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on your response sheet.

_____ 1. A good insulator has many free electrons.

_____ 2. Copper is an example of a good conductor.

_____ 3. Silver has many free electrons.

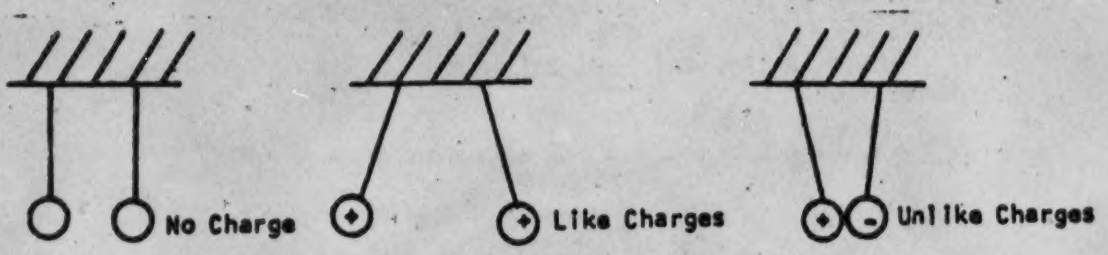
_____ 4. Rubber is an example of a good insulator.

_____ 5. All materials contain the same number of free electrons.

Answers to Frame 7: 1.__ 2. T 3. T 4. T 5. _

Frame 8

Static electricity can be made in a number of ways. You will from time to time feel a shock when you touch the door handle of a car after sliding over its plastic seat covers. The friction made between glass and silk when rubbed with each other will make static electricity the same way as air passing over the skin of an aircraft. Static electricity is generally considered to be electricity at rest. A charged body is one that has more or less than the normal number of electrons. A neutral body is one that has an equal number of electrons and protons in each atom. It can be shown in the figure below that bodies with like charges will push each other apart and those with unlike charges will draw to each other.



DO NOT MARK IN THIS TEXT

Mark the correct answer for each of the following questions on the response sheet.

_____ 1. An atom that has three electrons and two protons would be

a. negatively charged.
b. positively charged.

_____ 2. Two bodies which attract to each other are called

a. positively charged bodies.
b. negatively charged bodies.
c. unlike charged bodies.

_____ 3. Static electricity is sometimes referred to as electricity at rest.

a. True
b. False

Answers to Frame 9: 1. T 2. T 3. T

Frame 10

A grounding wire can be used to connect a body to the earth to drain its static charges. Fro example, a grounding wire is used to connect the aircraft and fuel truck to the earth during refueling. A static discharger is a rubber cotton wick which has graphite in it. It si hooked to the trailing edge of the wings, rudders and elevators. It has a sharp point on the end, which gives the excess electrons a path to flow off of the aircraft to the air. The purpose of the static discharger is to eliminate the static charge that is caused by the flow of air over the skin of the aircraft during flight. A bonding wire is used to connect metal parts to each other on the aircraft so that all parts on it will have the same charge. If the aircraft is properly bonded, there will not be any difference in charges between various aircraft parts. As stated earlier, if each body has a different charge these charges will try to equalize and sparking will occur. This could also cause an aircraft fire.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on your response sheet.

_____1. The static discharger is used to connect an object to the earth to eliminate static charges.

_____2. Bonding wires are used so that all metal parts of the aircraft have an equal amount and the same polarity of charge.

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Answers to Frame 8: 1. a 2. c 3. a

Frame 9

Static electricity is always present as a hazard around aircraft when bodies of unlike charges are placed close to each other. The charges will try to become equal with each other. When this happens, there will be a small spark jumping from one body to the other body. The greatest hazard here is that this spark can cause fires.

Another problem is that it can cause radio static noise and shock. There are a lot of things used to help reduce the number of hazards from static electricity. Some of these things are grounding wire, static dischargers and bonding wires.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on your response sheet.

_____ 1. Shock is one hazard of static electricity.

_____ 2. Unlike charges will try to equalize when brought together.

_____ 3. Fire can be caused by sparks created by static electricity.

Answers to Frame 10: 1. _ 2. T

Frame 11

Match the terms on the right to their description or examples on the left. Place the correct letter in the blanks provided on the response sheet.

NOTE: The letters may be used more than once.

_____ 1. Contains many free electrons.

_____ 2. Contains few loosely held electrons

_____ 3. Rubber

_____ 4. Copper

_____ 5. Silver

_____ 6. Glass

_____ 7. Aluminum

a. Insulator

b. Good conductor

Mark the following true statements with a "T" on your response sheet.

_____ 8. Two bodies that are positively charged will repel each other.

_____ 9. An atom that has 12 electrons and 11 protons would be an example of a charged body.

_____ 10. The greatest hazard of static electricity around an aircraft is fire.

_____ 11. A ground wire is used to help eliminate static charge.

_____ 12. An electron has a small negative charge.

_____ 13. A positive ion has more protons than electrons.

_____ 14. An atom with 13 electrons and 12 protons is an example of a negative ion.

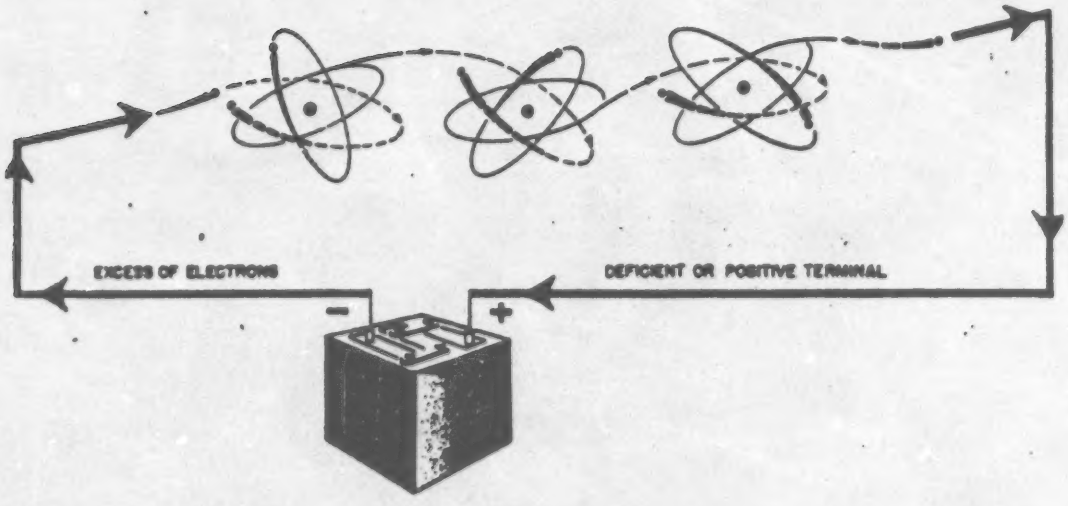
_____ 15. The subatomic particle that has a negative charge is the neutron.

_____ 16. The proton revolves around the nucleus in paths called shells.

Answers to Frame 11: 1. b 2. a 3. a 4. b 5. b 6. a
7. b 8. T 9. T 10. T 11. T 12. T
13. T 14. T 15. _ 16. _

Frame 12

Earlier you learned that the electrons in the outer shell of an atom may be forced from that atom by some external force. Suppose that a copper wire is connected between two charged bodies as shown below. Remember that copper is a very good conductor and has many free electrons. On one end of the body is a positive charge and at the other end is a negative charge. This means that the positive body has a low sum of electrons and the negative body has an excess sum of electrons. The negative side will repel the free electrons through the copper wire as shown by the arrows. Also, the positive charged mass can be thought of as attracting the electrons. As one electron is forced away from its atom, it makes that atom positively charged. With this atom now at a positive charge, it will try to pull an electron from a close at hand, negative or stable atom, into its own orbit. This is what makes that atom take on a different negative atom. The movement of electrons will keep taking place until the two bodies are the same. This flow of electrons is called CURRENT FLOW.



Electron movement through a conductor.

Frame 12 (Cont'd)

DO NOT MARK IN THIS TEXT

Mark the correct answer for each of the following questions on the response sheet.

_____ 1. The flow of electrons through a conductor is called

a. voltage
b. current

_____ 2. The electron is a small

a. negative charge
b. positive charge

_____ 3. The free electrons move from negative force toward the positive force.

a. True
b. False

Frame 13

In the last frame you learned that electrons will stop flowing between the charged bodies when the bodies become equally charged. In electrical circuits current must flow all the time. Thus, there must be some source that will keep the two points at different pressures so that the electrons will keep on flowing. A source of this type is called a source of electromotive force. Electromotive force (EMF) is a force which will cause electrons to move through a conductor. It is very important that you understand the differences between current (I) and electromotive (EMF) force. EMF was defined as the FORCE THAT CAUSES ELECTRONS TO MOVE THROUGH A CONDUCTOR. Current was defined as the ACTUAL MOVEMENT OF ELECTRONS THROUGH A CONDUCTOR.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on your response sheet.

_____ 1. Electromotive force and current have similar meanings.

_____ 2. In order to have electron flow you must have EMF.

Answers to Frame 12: 1. b 2. a 3. a

Answers to Frame 13: 1. _ 2. T

Frame 14

We now know that in order to have current flow through a conductor we must have a difference in pressure between the two points that the conductor is connected to. This difference in pressure is generally referred to as potential difference or a difference in potential. Tow of the most common sources of EMF are batteries and generators. We'll discuss these in a later lesson. The unit of measure for EMF is the volt. From the term bolt the word voltage has come into use to mean the same as EMF. The symbol used to represent voltage, potential difference, EMF, or electrical pressure is E.

Mark the following true statements with a "T" on your response sheet.

_____1. Voltage and EMF have similar meaning.

_____2. An EMF can be used to provide a continuous flow of electrons.

_____3. The unit of measure for EMF is volt.

Fill in the blanks with the correct term on your response sheet.

4. The movement of electrons from a negative to a positive potential is called _____.

5. The force that causes electrons to move through a conductor is called _____.

Answers to Frame 14: 1. T 2. T 3. T 4. current

5. voltage or EMF

Frame 15

We know that a good conductor, such as copper, contains many free electrons. When one electron leaves the negative terminal of a source of EMF, it immediately repels a free electron from an atom in the wire. This free electron repels another free electron, etc. A chain reaction takes place throughout the entire conductor. At the same time that one electron leaves the negative terminal, a free electron moves from the conductor into the positive terminal. The net effect of this movement is felt instantaneously between the terminals and through the conductor. The process that goes on inside a source of EMF to keep the negative terminal supplied with an excess of electrons will be explained in a later lesson. The rate at which electrons pass a given point in a conductor is a measure of the amount of current flowing. The unit of measure for current flow is the ampere. The symbol which is usually used to represent electric current is I, which means amount of current.

Mark the correct answer for each of the following questions on the response sheet.

_____ 1. The unit of measure for current flow is

a. EMF.
b. voltage.
c. electron.
d. ampere.

_____ 2. The symbol used to represent electric current is

a. E.
b. I.
c. R.
d. P.

_____ 3. Current is the flow of electrons through a

a. conductor.
b. non-conductor.

_____ 4. The symbol for voltage is

a. I.
b. R.
c. Y.
d. E.

Answers to Frame 15: 1. d 2. b 3. a 4. d

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Frame 16

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on your response sheet.

_____1. The proton has a positive charge on it.

_____2. The electron orbits around the nucleus in paths, called shells.

_____3. An atom that has lost an electron would be called a negative ion.

_____4. Normally an atom is electrically neutral.

_____5. Silver is an example of a good conductor.

_____6. A good insulator such as glass has few loosely held electrons.

_____7. Copper has many free electrons.

_____8. Two bodies that are positive charges will attract each other.

_____9. Static electricity can cause fires.

____10. An atom with 12 electrons and 12 protons is an example of a charged body.

Match the terms or symbols on the right to their definition or the term they sumbolize. Place the correct letter on the blanks provided on the response sheet.

11. Force that causes electrons to move through a conductor.

12. The movement of electrons through a conductor.

13. Symbol vor voltage.

14. Symbol for current.

Fill in each blank with the correct term or letter on the response sheet.

15. The unit of measure for EMF is the _____.
16. The unit of measure for current is the _____.
17. In the figure shown below, the electrons will move from point _____ to point _____.

COPPER WIRE

Answers to Frame 16: 1. T 2. T 3. _ 4. T 5. T 6. T 7. T
8. _ 9. T 10. _ 11. c 12. d 13. a
14. b 15. volt 16. ampere 17. A to B

Frame 17

Since conductors have many free electrons, they will permit a large current to flow in response to little EMF. Since insulators contain very few free electrons, they will permit relatively little current flow in response to a large or great EMF. Actually no material is a perfect insulator. All materials have some free electrons that will flow as current. On the other hand even the best conducting materials available have some opposition to current flow. This opposition to current flow is called resistance. The letter R is used as the symbol for resistance and the unit of measure of resistance is the ohm. A conductor has a resistance of one ohm when an applied voltage of one volt causes a current of one ampere to flow through it.

Fill in each blank with the correct term or symbol on the response sheet.

1. The symbol for current is _____.

2. The symbol for resistance is _____.

3. The unit of measure for voltage is the _____.

4. The opposition to current flow is called _____.

5. The force that causes current flow is called _____.

6. A material that contains very few free electrons is called a/an _____.

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Answers to Frame 17: 1. I 2. R 3. volt 4. resistance

5. voltage or EMF 6. insulator

Frame 18

Conductance is the ability of a material to conduct current; thus it is the opposite of resistance. A material with high conductance would have many free electrons. Copper would have high conductance. A material such as glass, which does not conduct current very well, would have low conductance and high resistance. A material, such as copper, with high conductance would have low resistance, etc. The symbol for conductance is G. The unit of measure of conductance is the mho (ohm spelled backward).

Mark the following true statements with a "T" on your response sheet.

_____1. A substance such as rubber has relatively high conductance.

_____2. Silver has very high conductance and very low resistance.

Fill in each blank with the correct term or symbol on the response sheet.

3. The ability of a material to conduct current is called _____.

4. The symbol for voltage is _____.

5. The symbol for conductance is _____.

6. The symbol for resistance is _____.

7. The unit of measure for resistance is the _____.

8. The unit of measure for conductance is the _____.

9. The movement of electrons through a conductor is called _____.

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Answers to Frame 18: 1. _ 2. I 3. conductance 4. _ 5. G 6. R 7. ohm 8. mho 9. current

Frame 19

For each of the following descriptions write on the response sheet the term described, the symbol for the term, and the unit of measure for the term. A list of terms, symbols, and units are given for you to use; but the information on any one line is not correctly related.

DO NOT MARK IN THIS TEXT

TERMS	SYMBOLS	UNITS OF MEASURE
Voltage	1	Ohm
Current	R	Mho
Resistance	E	Volt
Conductance	G	Ampere

TERM	SYMBOL OF TERM	UNIT OF MEASURE	
_____	_____	_____	1. Opposition to current flow.
_____	_____	_____	2. Ability of a material to conduct current.
_____	_____	_____	3. Flow of electrons through a conductor.
_____	_____	_____	4. Force that causes the flow of electrons through a conductor.

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Answers to Frame 19:

TERMS	SYMBOLS	UNITS OF MEASUREMENT	
resistance	R	Ohm	1.
conductance	G	Mho	2.
current	I	Ampere	3.
voltage	E	Volt	4.

Frame 20

The size and type of material of the wires used in electrical circuits are chosen so as to keep the electrical resistance as low as possible. The electrical resistance of a wire will depend on: (1) its length, (2) its diameter, (3) the type of material, and (4) the temperature. For a given material at a fixed temperature, increasing the length will cause its resistance to increase. Doubling the length will double the resistance. However, the larger the diameter of a conductor, the lower will be its resistance to current flow. This is the reason why large diameter wires are used in high current flow circuits.

Look at the comparison between the figures shown below.

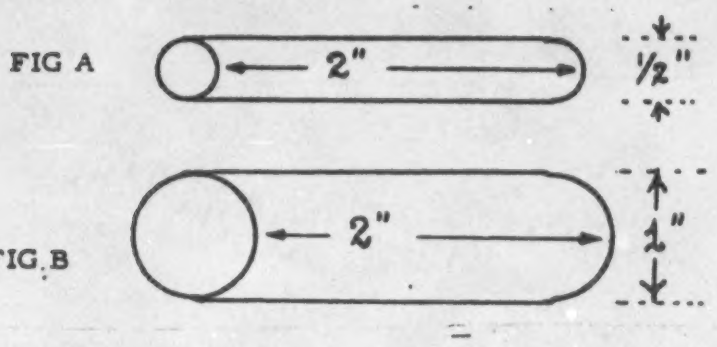

Figure B has twice as large a diameter as figure A. Since it is <u>twice as large in diameter</u> it will have many, many, more free electrons that can be moved and as a result it will have less "Resistance."

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Frame 20 (Cont'd)

In this illustration notice the difference in the LENGTH of the two conductors (wires).

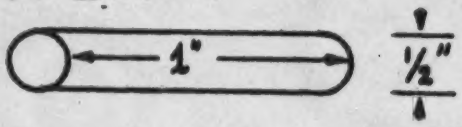
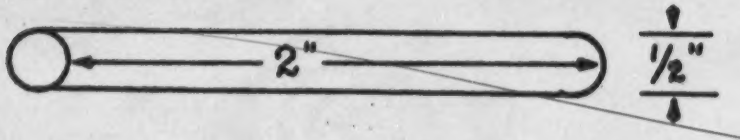
FIG A 

FIG B 

The conductor with the greatest length will have the greatest resistance because the electrons have further to travel.

Mark the following true statements with a "T" on your response sheet.

_____ 1. A piece of aluminum wire two feet long will have more resistance than one three feet long.

_____ 2. The larger the diameter of a copper wire, the less resistance it will have.

Frame 21

Different types of materials offer different amounts of resistance. Metals have low resistance whereas glass and rubber have high resistance. In most conductors (copper, aluminum, silver, iron, etc.) the resistance increases with an increase in temperature. These materials are said to have a positive temperature coefficient. The resistance of carbon and liquids decreases with an increase in temperature. These materials are said to have a negative temperature coefficient.

Mark the following true statements with a "T" on your response sheet.

_____ 1. Heating a piece of copper wire will cause its resistance to decrease.

_____ 2. Glass has very high resistance.

_____ 3. All materials increase in resistance when heated.

Answers to Frame 20: 1._ 2. T

Answers to Frame 21: 1. _ 2. T 3. _

Frame 22

In your own words write the definitions of each of the following terms on the response sheet.

1. Voltage_____

_____

2. Current_____

_____

3. Resistance_____

_____

4. Conductance_____

_____

For each of the following terms fill in the correct symbol on the response sheet.

	SYMBOL
5. Current	_____
6. Voltage	_____
7. Resistance	_____
8. Conductance	_____

Mark the following true statements with a "T" on your response sheet.

_____9. Heating a piece of aliminum wire will cause its resistance to increase.

_____10. The longer a wire is the more resistance it will have.

_____11. The larger the diameter of a wire the more resistance it will have.

_____12. Copper and aluminum have very low resistance.

_____13. The unit of measure for current is the ampere.

_____14. The unit of measure for conductance is the ohm.

_____15. The unit of measure EMF is the volt.

Answers to Frame 22:

1. the force that causes electrons to move through a conductor.

2. the movement of electrons through a conductor.

3. the opposition to the flow of electrons.

4. the ability of a material to conduct current.

5. I 6. E 7. R 8. G 9. T 10. T 11. _ 12. T 13. T

14. _ 15. T

Frame 23

The effects of current flow such as heat, chemical, shock, and magnetism depend for their intensity on the amount of current. Heat is produced when current flows through a conductor. You have probably seen applications of the heating effects of current. Also you probably have experienced electrical shock in one form or another. The chemical effect of current can be observed when charging a storage battery such as the one you have in your automobile. The magnetic effect can be both harmful and helpful. In the harmful category it can cause errors in some meters and compasses in aircraft, if not guarded against. In the useful category it makes possible the remote control of circuits. It is also used in voltage generation. You will study magnetism in greater depth in a later lesson.

Mark the correct answer for each of the following questions on the response sheet.

_____ 1. More heat is produced when the current flow through a conductor is

a. increased.
b. decreased.

Answers to Frame 23: 1. a

Frame 24

Match the terms on the right to their description on the left. Place the correct letter on each blank provided on the response sheet.

NOTE: Letters may be used more than once.

____ 1.	Positively charged	a. Neutron
____ 2.	Negatively charged	b. Proton
____ 3.	No electrical charge	c. Electron
____ 4.	Revolves around the nucleus	

Mark the following true statements with a "T" on your response sheet.

____ 5. A positive ion has more protons than electrons.

____ 6. Normally an atom has the same number of electrons as protons.

____ 7. An atom that has gained an electron would be called a negative ion.

____ 8. A good conductor contains many free electrons.

____ 9. An example of a good insulator is rubber.

____ 10. An example of a good conductor is copper.

____ 11. A good insulator has few free electrons.

____ 12. Like charges attract each other.

____ 13. An atom with nine electrons and seven protons would be positively charged.

____ 14. Electrons flow from a positive potential to a negative potential.

____ 15. EMF and voltage have similar meanings.

____ 16. The flow of electrons through a conductor is called voltage.

____ 17. Heating an aluminum wire will cause its resistance to increase.

____ 18. If all other factors are identical, a copper wire three feet long, will have more resistance than one two feet long.

____ 19. Copper has much lower resistance than rubber.

Frame 24 (Cont'd)

Fill in the blanks with the correct term on the response sheet.

20. The movement of electrons from a negative to a positive potential is called _____.

21. The force that causes electrons to move through a conductor is called _____.

22. The ability of a material to conduct current is called _____.

23. The opposition to the flow of electrons is called _____.

For each of the following terms on the response sheet, write the symbol and the unit of measure on the correct line. A list of symbols and units of measure are given below.

SYMBOLS	UNITS OF MEASURE
E	Mho
I	Ohm
R	Volt
C	Ampere

TERMS	SYMBOL	UNIT OF MEASURE
Resistance	24. _____	25. _____
Current	26. _____	27. _____
Conductance	28. _____	29. _____
Voltage	30. _____	31. _____

Answers to Frame 24: 1. b 2. c 3. a 4. c 5. T 6. T 7. T 8. T 9. T 10. T 11. T 12. _ 13. _ 14. _ 15. T 16. _ 17. T 18. T 19. T 20. current 21. voltage or EMF 22. conductance 23. resistance 24. R 25. ohm 26. I 27. ampere 28. G 29. mho 30. E 31. volt

PROGRAMMED TEXT
3ABR42331-PT-108

Technical Training

Aircraft Environmental Systems Mechanic

MAGNETISM

25 August 1977

3350 TECHNICAL TRAINING WING
3370 Technical Training Group
Chanute Air Force Base, Illinois

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DO NOT USE ON THE JOB

ATC FORM 214 (JAN 76) OBSOLETES ATC FORMS 214, MAY 69, 522, NOV 63 AND 523, MAY 71. STANDARD COVERSHEET

FOREWORD

This programmed text was prepared for use in the 3ABR42331 instructional system. The materials contained herein have been validated using 30 students enrolled in the 3ABR42331 course. Eighty percent of the students taking this text surpassed the criterion called for in the approved lesson objective. The average student required 2.3 hours to complete the text.

OBJECTIVES

Given a list of materials, select those that can be used to make temporary and permanent magnets.

Describe the laws and effects of lines of force.

Given diagrams of electromagnets, use principles of magnetism to identify effects of magnetism.

STANDARD

A minimum of 80% accuracy is required on the above objectives.

INSTRUCTIONS

This programmed text presents information in small steps called "FRAMES." Carefully study the written material and diagram if one is provided until you are satisfied that you understand its contents. Each frame requires you to respond to the information in some way. For example, you may be required to select the true statements, etc. Specific instructions are provided in each frame. After you have made your response on the response sheet, compare your answers with the answers given at the beginning of the next frame. If you are correct, go on to the next frame. If you are incorrect, study the frame again and correct your mistakes before continuing. Read carefully, select the correct answers and DO NOT HURRY. DO NOT WRITE IN THIS TEXT.

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Frame 1

Things such as metal are said to be a magnet if it has the power to draw to it such things as iron, steel, nickel, or cobalt, which are known as magnetic materials. There are two groups of magnets known as, natural magnets and artificial magnets. First we will discuss natural magnets. A natural magnet is found in the earth. Back in the days of the ancient Greeks, they knew that some stones found in the town of Magnesia, in Asia Minor, drew bits of iron to them. These stones were called magnetite. The Orientals learned that if a piece of these rocks were hung in a horizontal plane and allowed to turn, the same end would always point to the north. Then as time went on the Europeans learned of this discovery and used it as a navigator's compass to aid in navigation. Natural magnets have limited practical use because their magnetic force is not always the same and also very weak.

Mark the following true statements with a "T" on the response sheet.

_____1. Natural magnets have many practical uses.

_____2. Natural magnets are very weak magnets.

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Answer to Frame 1: F 1. T 2.

Frame 2

The first artificial magnets were made by touching the metal to be magnetized with a natural magnet. In later years it was found that an iron bar could be magnetized by aligning the bar with the magnetic field of the earth when it was being forged. In the modern times of today, magnets are made by placing a metal bar in a magnetic field made by an electrical current. We will look at this kind of magnetism later in this text. Man made magnets are made in a wide variety of sizes and shapes, and they are used mostly in electrical equipment. The bar magnet, the horseshoe magnet, and compass needle are the most common types of artificial magnets today. Any substance which is capable of being magnetized or can be drawn to a magnet is called a magnetic substance. Some common magnetic substances are iron, iron alloys such as steel and alnico, cobalt, and nickel. All of the substances that are not attracted by a magnet are usually called nonmagnetic substances. Some common examples of these are wood, glass, copper, and gold. For our purpose in this text, we are chiefly concerned with substances which are noticeably attracted by a magnet and as a result of that, we are not going to get involved in a more detailed classification system.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

_____1. A bar of alnico could be made into a magnet.

_____2. Glass is generally considered to be a nonmagnetic substance.

_____3. Artificial magnets can be made by using an electrical current.

Answers to Frame 2: __T__ 1. __T__ 2. __T__ 3.

Frame 3

Man made magnets may be termed as "permanent" or "temporary" depending on how well they can hold their magnetic strength after the magnetizing force has been removed. Filings of soft iron brought into contact with a magnet will become magnetized and act as small magnets which will in turn draw other soft iron filings to it. When the soft iron filings are removed from the magnet, they will lose their magnetic properties fast. Any magnet which loses its magnetism in a very short time is called a temporary magnet. Substances such as hard steel and alnico will become highly magnetized when brought into contact with a magnet or close to a strong magnetic field. The state of magnetism will be held over a long period of time. Any magnet which can hold its magnetism over a long period of time is called a permanent magnet.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

_____1. Hard steel can be made into a good permanent magnet.

_____2. Temporary magnets retain their magnetism for long periods.

_____3. Soft iron makes good permanent magnets.

Answers to Frame 3: __T__1. _____2. _____3.

Frame 4

When a bar magnet labeled A in figure 1 below, is suspended so that it is free to swing, it will swing around and come to rest with one end pointing nearly due north. When this effect was first established, it was decided arbitrarily to call the north-seeking end of the magnet a north pole. The other end was called the south pole. These designations for the ends of a magnet are still used. Frequently, permanent magnets are marked N at the north pole and S at the south pole. If the north pole of a second magnet, labeled B in figure 2, is brought into the vicinity of the north pole of the suspended magnet A, magnet A will be pushed away in the direction of the arrow at that point. From this effect we have the following fundamental law of magnetism: <u>like magnetic poles repel each other</u>. If the south pole of magnet B in figure 3 is placed into the vicinity of the north pole of magnet A, magnet A will be pulled in the direction of the arrow at that point. This effect forms the basis of another fundamental law of magnetism: <u>Unlike magnetic poles attract</u> each other.

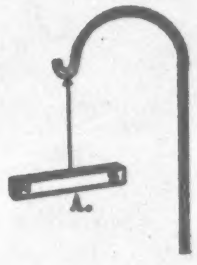


Figure 1.

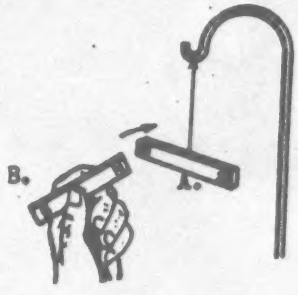


Figure 2.

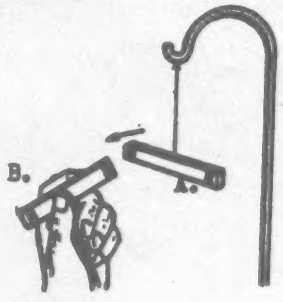


Figure 3.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

_____1. Two south magnetic poles will attract each other.

_____2. The magnet in figure 1 will have its north pole pointing nearly due north.

_____3. Figure 3 shows an example of two magnets repelling each other.

Answers to Frame 4: ____1. __T__2. ____3.

Frame 5

If a bar magnet is dipped into filings, a large number of those filings will cling to the magnet near its ends, but very few will attach themselves to the magnet near its center. See figure 4 below. This shows that the magnetic force is concentrated at the ends or poles of the magnet. The space surrounding a magnet, in which the magnetic force acts, is called a magnetic field. An experiment has been done for you, in figure 5, using a magnet, a piece of paper, and some iron filings used to show the invisible magnetic field pattern around a magnet. One point you should remember is that you are not looking at the magnetic field itself, because the field is invisible; you are looking at the filings which are used to detect the magnetic field. The magnetic field around the magnet causes the iron filings to form themselves into lines that circle the magnet. These lines are called lines of force.

Figure 4.

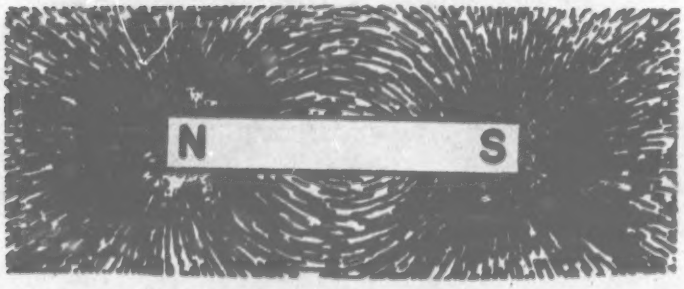


Figure 5.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

____1. A large number of iron filings will attach themselves to the center of a magnet.

____2. The area around a magnet where its force can be felt is called its magnetic field.

____3. From studying figure 1 you might estimate that the magnetic field around the S pole of the magnet is as strong as the field around the N pole.

Answers to Frame 5: ____1. __T__2. __T__3.

Frame 6

In frame 5, we saw the magnetic field pattern around a magnet. A simple and more commonly used method is that of arbitrarily representing the forces in a magnetic field by drawing a few lines called lines of force. See figure 6 below. Note one thing in particular that is revealed by figure 6; the concentration of magnetic field within the metallic bar is very great, while the concentration of the external field decreases very rapidly with distance from the poles. Observe also that arrowheads have been placed on each of the lines of force of the external field. The direction of the arrowheads is away from the north pole and toward the south pole of the magnet. In other words the arrowheads indicate that the lines of force leave the magnet at the north pole and enter the magnet at the south pole. Within the substance of the magnet the direction of the force is assumed to be from the south pole to the north pole so that a continuous loop is formed by each line of force. The direction of magnetic lines of force is defined as the direction in which the north pole of a compass needle will point if placed at any point along a line of force.

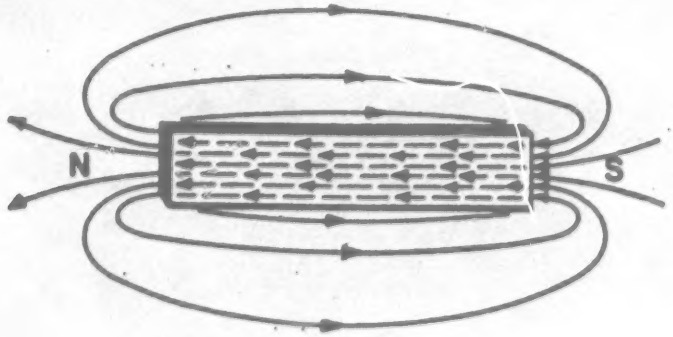


Figure 6.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

____1. The farther you are from a magnet the stronger the magnetic force is.

____2. The lines of force go from north to south inside the magnet.

____3. The magnetic field is concentrated inside the magnet.

____4. Each line of force forms a continuous loop.

Answers to Frame 6: ____1. ____2. __T__3. __T__4.

Frame 7

There are two forces which act upon the lines of force. One is the mutually repellant force that causes them to try to spread out as far away from one another as possible. The other is the force of attraction that they have for the south pole of the magnet; that is as they travel externally from the north pole to the south pole, they try to take the shortest path to the south pole. These two opposing forces account for the pattern of the lines of force that are formed around the magnet. The two opposing forces acting upon the lines of force cause the lines of force to behave as if they were elastic bands stretched out in the field of the magnet. Because of this, if the magnetic force decreases, the lines of force will tend to collapse toward the magnet. If the magnetic field is increased, the lines of force will expand. The greater the strength of the magnet, the farther out into space surrounding the magnet its magnetic force will extend. Also, when the strength of a magnet is increased, the number of lines of force in the magnetic field will also increase. This increased number of lines of force results in the lines being closer together.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

____1. The stronger the magnetic field the more lines of force that a magnet will have.

____2. Lines of force act as if they are elastic bands.

____3. The greater the strength of a magnet, the closer together the lines of force are.

Answers to Frame 7: T 1. T 2. T 3.

Frame 8

There are several basic laws concerning magnetic fields. We have already discussed that (1) lines of force travel from north pole to south pole outside the magnet (south to north inside the magnet); (2) lines of force form continuous loops; and (3) lines of force are elastic and act as if under tension. In figure 6, we observed that the lines of force never crossed one another. Magnetic fields (lines of force) have no known insulator. There is no known substance in the world through which a magnetic field cannot pass.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

_____1. Rubber does not allow the passage of lines of force.

_____2. Lines of force will never cross one another.

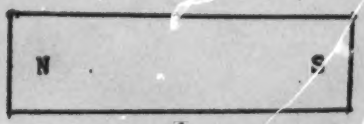
_____3. Lines of force are only continuous on the outside of the magnet.

_____4. Lines of force travel from north to south outside the magnet.

Answers to Frame 8: ____1. T 2. ____3. T 4.

Frame 9

When a bar magnet is broken into two separate pieces (refer to figure 7 below) it can be easily shown that each piece will have a north pole and a south pole. The piece which contains the north pole of the original magnet will establish a south pole at the end where the break occurred, and the piece that had the south pole of the original magnet will establish a north pole at the end where the break occurred. Each of the broken pieces of the original magnet can be broken into two more pieces and you will have four magnets. Each time the magnet is broken, a new pole is established at the newly broken end and that pole is of the opposite type to the pole at the other end. If you would continue to break the magnet successively in half until molecular size were obtained, you would find that the tiny molecule is a magnet possessing both a north pole and a south pole, with its own magnetic field.



A

Poles of a bar magnet

B

Poles of a bar magnet
After breakage

Figure 7.

These tiny magnets which are so small that they cannot be seen with a microscope, are thought of as being originally jumbled at random, with no definite order. This is illustrated in part A of figure 8. Considering that these molecules are tiny magnets, you might expect that they would automatically align themselves to form a magnet. Internal stress in the iron or steel can override the small magnetic fields of these magnets and hold them immobile, so that they maintain their haphazard alignment. An artificial magnet can be made by stroking an iron or steel bar with a permanent magnet, as shown in part A of figure 8, provided that the strokes are made in the same direction. If this process is continued, we can align the molecules as shown in part B of figure 8 and we have a magnet. This process is referred to as magnetic induction. Heating or jarring a magnet greatly weakens its magnetic force, since both of these processes make it easier for the molecules to move back to their randomly oriented position.

Frame 9 (Continued)

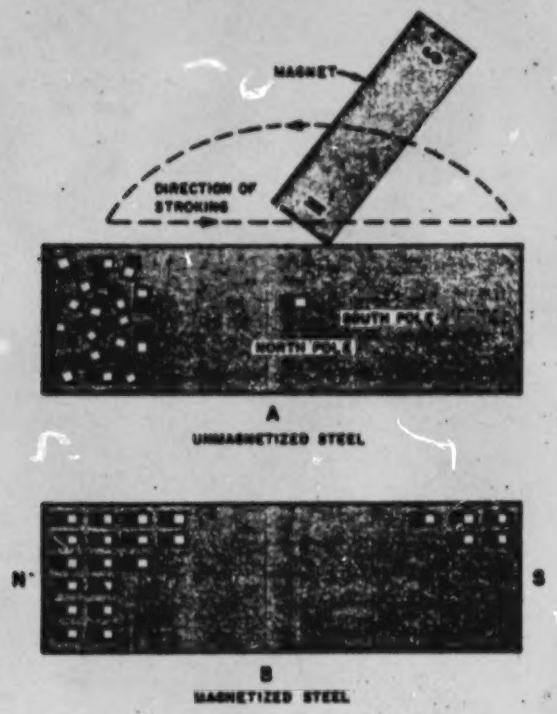


Figure 8.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

____1. A magnet is thought to be composed of many tiny magnets, each with its own magnetic field.

____2. The molecules of steel will automatically align themselves to form a magnet.

Answers to Frame 9: __T__1. _____2.

Frame 10

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

_____1. Flow from south to north inside the magnet.

_____2. Form continuous loops.

_____3. Will pass through any substance.

_____4. Will cross only at the poles.

_____5. Are concentrated inside the magnet.

_____6. Are elastic and act as if under tension.

Write the letter for one correct answer of the four given on the response sheet.

7. Which of the following substances are used in making temporary magnets?

   a. Hard steel.

   b. Soft iron.

   c. Soft silver.

   d. Glass.

8. Which of the following substances are used in making permanent magnets?

   a. Hard steel.

   b. Soft iron.

   c. Soft silver.

   d. Glass.

Frame 10 (Continued)

DO NOT MARK IN THIS TEXT.

MARK the following true statements with a "T" on the response sheet.

_____9. Unlike magnetic poles repel each other.

____10. Permanent magnets retain their magnetism for long periods of time.

____11. The space surrounding a magnet in which the magnetic lines of force exist is called a magnetic field.

____12. If a magnet is broken in half, it will no longer have any magnetic strength.

____13. All of the following are good magnetic substances: alnico, cobalt, steel, and gold.

Answers to Frame 10: T 1. T 2. T 3. ____4. T 5.

T 6. 7. b 8. a ____9. T 10.

T 11. ____12. ____13.

Frame 11

There are a few terms related to magnetism that you should be familiar with. The first term is permeability, which is the measure of the ease with which a given material can conduct magnetic lines of force as compared to air. The permeability of a vacuum is chosen to have a value of 1. The permeability of air has a value of 1.00004; thus, for all practical purposes it can be considered as equal to 1. The permeability of iron is very high, depending upon the grade, generally about 10,000. This means that the magnetic field will find a path through iron that is 10,000 times easier to follow than that through air. The property of permeability is used to direct and concentrate a magnetic field with respect to a given point in space. Figure 9 shows how a magnetic field between the north and south poles of a bar magnet is distorted or directed into a desired path through a soft iron bar. An important application of this property of permeability is the use of magnetic shields, which are made of highly permeable materials, such as soft iron, to protect delicate instruments from damage due to an external magnetic field. If any magnetic substance is placed in a magnetic field it can become mangetized. Many delicate instruments, such as watches and meters, are rendered quite useless if some of their parts become magnetized.

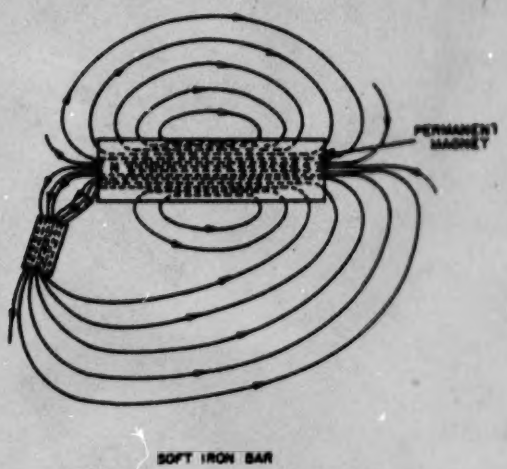


Figure 9.

If, as in figure 10, a soft iron ring is placed around the instrument to be protected, the lines of force from the magnetic source will follow the permeable path through the soft ring, and thus be deflected away from the instrument inside. Your watch is probably another example of shielding. The back of it probably specifies that your watch is antimagnetic or nonmagnetic. This means that the back is made up of a highly permeable material.

Frame 11 (Continued)

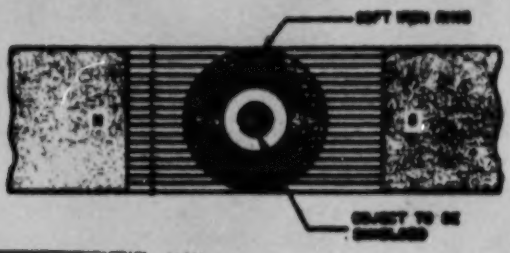


Figure 10.

DO NOT MARK IN THIS TEXT.

Fill in each blank with the correct term on the response sheet.

1. The measure of the ease with which a given material can conduct magnetic lines of force as compared to air is called _____.

2. A highly permeable substance used to protect a delicate instrument from magnetic lines of force is called a _____.

Answers to Frame 11: 1. permeability 2. magnetic shield

Frame 12

Another term that you should be familiar with is retentivity, which is the ability of a material to retain its magnetism. Since steel holds its magnetism longer than soft iron, steel has much more retentivity than does soft iron. It means that a material with good retentivity will make a good permanent magnet. Another term that is very similar to retentivity is residual magnetism.

Residual magnetism is the amount of magnetism held by a substance after the magnetizing force has been removed.

Hard steel will have very high residual magnetism so it has high retentivity, whereas, soft iron will have small amounts of residual magnetism and a low retentivity.

DO NOT MARK IN THIS TEXT.

Fill in the blanks with the correct terms on the response sheet.

1. The amount of magnetism retained by a substance after the magnetizing force is removed is called _____.

2. The ability of a material to retain its magnetism is called _____.

3. Temporary magnets have (small/large) _____ amounts of residual magnetism and (high/low) _____ retentivity.

4. Permanent magnets have (high/low) _____ retentivity and large amounts of _____ magnetism.

Answers to Frame 12: 1. residual magnetism 2. retentivity

3. small, low 4. high, residual

Frame 13

The next term you will be concerned with in your study of magnetism is magnetic saturation. A substance is said to be magnetically saturated if increasing the strength of the magnetizing force will not produce any additional magnetic field in the substance. The type of material that is being magnetized will determine the point where the material becomes magnetically saturated. Soft iron has a much lower saturation point than steel or alnico.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

_____1. All magnetic materials have the same saturation point.

_____2. Increasing the strength of the magnetic source above the saturation point will cause a rapid increase in magnetism of the material being magnetized.

_____3. Steel will reach its saturation point before soft iron.

Answers to Frame 13: _____1. _____2. _____3.

Frame 14

DO NOT MARK IN THIS TEXT.

Match the terms on the right to their definition on the left by placing the correct letter in the blank provided on the response sheet.

	DEFINITIONS		TERMS
_____1.	Highly permeable material used to protect delicate instruments from damage due to an external magnetic field.	a.	Magnetic saturation
		b.	Permeability
		c.	Magnetic shield
_____2.	Measure of ease with which a given material can conduct lines of force.	d.	Residual magnetism
		e.	Retentivity
_____3.	Ability of a material to retain its magnetism.		
_____4.	Point where the magnetic strength of a material will not increase with an increase in the magnetizing force.		
_____5.	Amount of magnetism retained by a substance after the magnetizing force is removed.		

Mark the following true statements with a "T" on the response sheet.

_____6. Soft iron will make a good permanent magnet.

_____7. A permanent magnet will retain its magnetic force for a long period of time.

_____8. Two north poles will attract each other.

_____9. Magnetic field is concentrated inside the magnet.

____10. The stronger the magnetic field the more lines of force that a magnet will have.

____11. Lines of force flow urom north to south outside the magnet.

____12. Hard steel will have higher retentivity than soft iron.

Answers to Frame 14: c 1. b 2. a 3. a 4. d 5.
6. T 7. 8. T 9. T 10.
T 11. T 12.

Frame 15

Up to this point we have been concerned with the characteristics of magnets and their magnetic fields. In the next frames you will begin to see the tie-in between magnetism and current flow. You will learn how an electromagnet works and see some examples of how we use magnets.

An electric current has with it certain magnetic effects and these effects obey definite laws. If a compass is placed close to a current carrying conductor, the needle aligns itself at right angles to the wire, thus, it shows that a magnetic field is there, see figure 12 below. The presence of this magnetic force can be shown by sprinkling iron filings on the flat piece of paper this current carrying conductor goes through, see figure 11 below. This shows that a magnetic field exists in circular form around the wire.

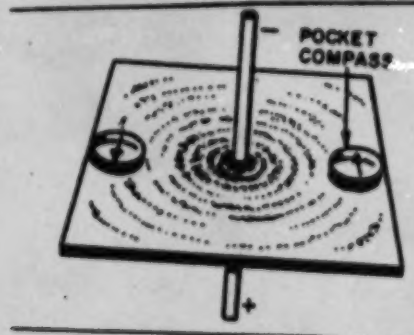


Figure 11.

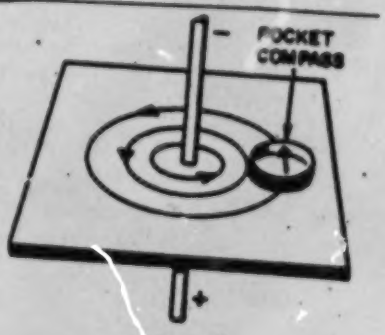


Figure 12.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

____1. Lines of force exist around a conductor that has current flowing in it.

____2. Lines of force form complete circular loops around a current carrying conductor.

____3. A conductor will always have a magnetic field around it.

Answers to Frame 15: __T__ 1. __T__ 2. ____ 3.

Frame 16

In the last frame we saw that a magnetic field does exist around a current carrying conductor (wire). This magnetic field is very much like the magnetic field around a permanent magnet. We also saw that the lines of force do form circles around a current carrying conductor. Each line of force around the wire acts much like an elastic band. When current in the wire goes up more lines of force are stretched farther out from the wires, but as soon as current flow goes down, some lines spring back toward the wire. Thus lines of force act as if they were under tension. The circular lines around the conductor in figure 13 below show that the lines of force are all along the full length of the wire.

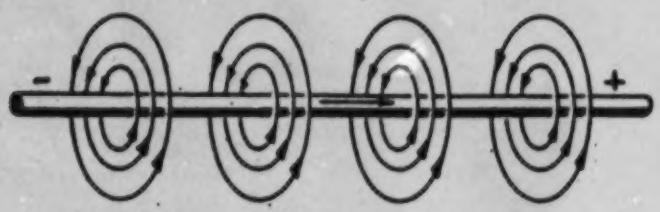


Figure 13.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" concerning lines of force around a current carrying conductor on the response sheet.

____1. Form complete circles around the conductor.

____2. Act as if they are under tension.

____3. Extend farther into space when the current flow through the conductor is increased.

Answers to Frame 16: T 1. T 2. T 3.

Frame 17

Lines of force around a conductor have another distinguishing trait in that they form at right angles to the direction of current flow. The magnetic field around a straight conductor does not have a north or a south pole since the lines of force are in circles. The way in which current is flowing through a conductor determines the direction of the magnetic field around it. A simple rule used to find the direction of the magnetic field when the direction of current flow is known is the left hand rule. It can be stated as follows: Grasp the conductor in the left hand with the thumb pointing in the direction of current flow as shown in figure 14 below. The fingers will point the way the magnetic field goes around the conductor. This rule can also be used to find the direction of current flow through a conductor, if the direction of the magnetic field is known.

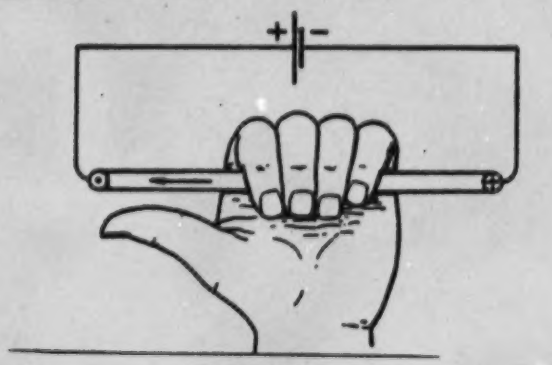


Figure 14.

DO NOT MARK IN THIS TEXT.

Fill in the blanks with the correct word(s) on the response sheet.

1. The direction of the magnetic field is determined by the direction of the _____ through the conductor.

2. Reversing the current through a conductor will _____ the direction of the magnetic field surrounding it.

3. Increasing the amount of current flowing through a conductor will _____ the strength of the magnetic field around it.

Answers to Frame 17: 1. current flow 2. reverse 3. increase

Frame 18

If a wire is bent into the form of a loop, all of the lines of force will go on and circle the conductor as they did when the wire was straight. Figure 15 below shows that each line of force will pass through the center or inside of the wire loop in the same direction. Each line of force will then circle around the outside of the wire loop to complete its path. The lines of force are concentrated inside the wire loop causing the magnetic strength inside the wire loop to increase.

Figure 15.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

_____1. The lines of force on the inside of a conductor loop will be in the same direction.

_____2. Reversing the direction of current flow through the loop will cause the direction of the lines of force to reverse direction.

_____3. The lines of force on the inside of a conductor loop will oppose one another and cancel the magnetic effect.

Answers to Frame 18: __T__ 1. __T__ 2. _____ 3.

Frame 19

If you can remember the path taken by lines of force in a bar magnet, you will see that it is almost the same as the lines of force through a loop of wire. Lines of force in a bar magnet all go one way inside the magnet, then each line completes its loop by circling outside the magnet. A loop of wire has poles just like a bar magnet. All lines of force go in one side of the loop and leave from the other side of the loop. Thus, a north pole is made on one face of the loop and a south pole on the other. See figure 16 below. The side of the loop into which the lines of force enter is the south pole, while the side from which the lines of force leave is the north pole. Magnets made by current flow through coils obey the same fundamental laws of magnetism (like poles repel and unlike poles attract) as do permanent magnets.

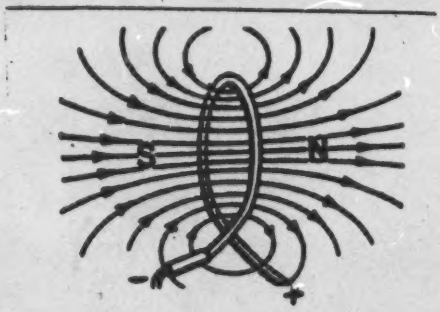


Figure 16.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

_____1. Lines of force flow from north to south inside the loop of a current-carrying wire.

_____2. The magnetic field around a straight conductor has a north and south pole.

_____3. The magnetic field created by the loop of a current-carrying conductor is very similar to that of a bar magnet.

_____4. A loop of wire with current flowing has a north and a south pole.

_____5. If you placed two current-carrying coils so that the north poles faced each other, the coils would be pushed away from each other.

Answers to Frame 19: ____1. ____2. T 3. T 4. T 5.

Frame 20

The magnetic fields of two parallel wires with their current flowing in the same direction are shown in figure 17 below.

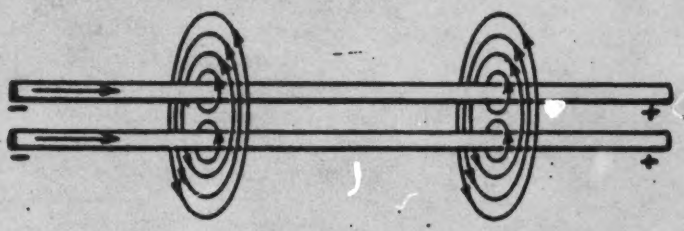


Figure 17.

Notice that in the area between the conductors, the magnetic lines of force oppose each other, while the rest of the lines of force join to form complete magnetic loops which are stronger than the field around either of the separate conductors. The magnetic fields of the two conductors will join only if the currents are flowing in the same direction.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

____1. The magnetic fields of two parallel conductors with current flow in the same direction will be additive.

____2. The magnetic fields of two parallel conductors with current flow in opposite directions will be additive.

____3. The magnetic lines of force between two parallel conductors with current flow in the same direction will combine.

____4. The number of parallel conductors with current flowing in the same direction determine the overall magnetic strength.

Answers to Frame 20: __T__ 1. _____ 2. _____ 3. __T__ 4.

Frame 21

When a wire is wound into a coil of many loops or turns, the magnetic fields around all the loops of wire tend to join to form a large magnetic field. The magnetic field of this coil goes one way inside the coil and the opposite way outside the coil. See figure 18 below. The external lines of force leave the coil at the north pole and go back to the coil at the south pole, just as in a permanent magnet. The same fundamental laws of magnetism apply here also. The polarity of a coil (north or south pole) is determined by the way current flows through the coil windings.

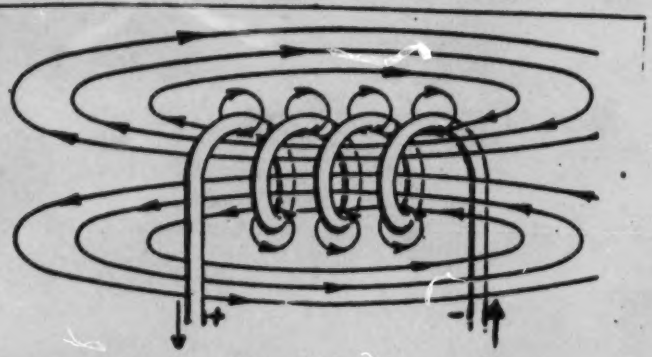


Figure 18.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

_____1. The polarity of a coil will remain the same when current direction is reversed through it.

_____2. Lines of force travel from north to south inside of a coil.

_____3. Adding more turns on a coil will cause the coil's magnetic strength to increase.

Answers to Frame 21: ____1. ____2. T 3.

Frame 22

Because the direction of the magnetic field (polarity) of a coil depends on the direction of the current flow through the coil, it is possible to figure out which end of the coil is the north pole. A simple rule was made to do this. This rule is referred to as the left hand rule. This rule is as follows: Grasp the coil in your left hand with your fingers pointing in the direction of current flow through the coil windings, as shown in figure 19 below. Your thumb will point toward the north pole of the coil. Care must be taken to be sure the fingers point in the direction of current flow through the coil windings.

Figure 19.

DO NOT MARK IN THIS TEXT.

Fill in the blanks with the correct words on the response sheet.

1. In using the left hand rule as in figure 19 above, your _____ point in the direction of current flow, and your _____ points toward the north pole of the coil.

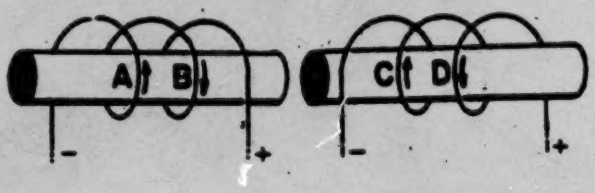
Answers to Frame 21: fingers, thumb

Frame 23

DO NOT MARK IN THIS TEXT.

Choose one of the four answers given and write its letter on the response sheet.

1. The direction of current through these coils is correctly indicated by



a. arrows A and C.

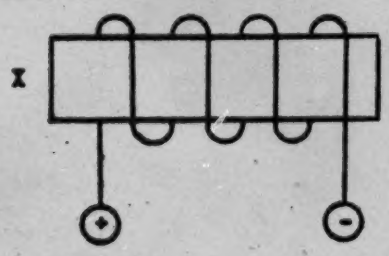
b. arrows B and D.

c. arrows A and D.

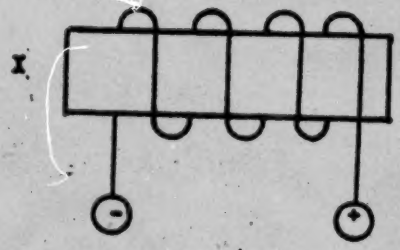
d. arrows B and C.

2. Circle the letters of the coils that have a north polarity at point X.

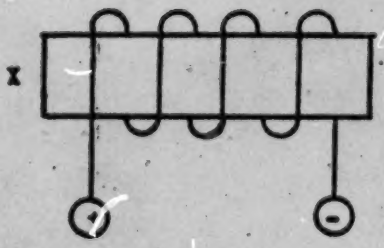
a.



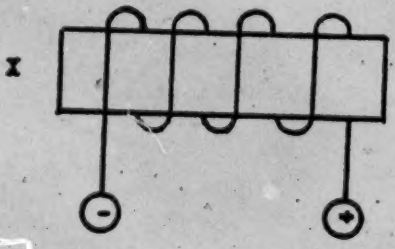
c.



b.



d.



Answers to Frame 23: 1. d 2. b, c

Frame 24

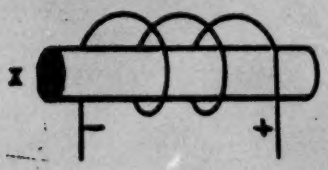
In the last frame you should have seen that if the coil winding direction remains the same and the direction of current flow is reversed, the polarity of the coil will be reversed. The same is true, if the direction of current remains the same and the direction of the coil winding is reversed; the polarity will also reverse. If the direction of winding and current flow are both reversed the polarity will remain the same.

DO NOT MARK IN THIS TEXT.

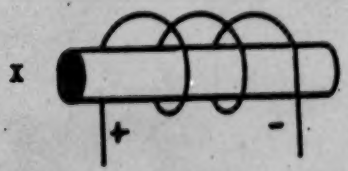
Choose one of the two answers given and write its letter on the response sheet.

1. Which coil has the south pole at point X?

a.



b.



Answer to Frame 24: 1. b

Frame 25

There are several things which will effect the magnetic strength of a coil. One of these is the amount of current flowing through the coil. When current flow increases, the magnetic strength of the coil will also increase. This factor is easy to control because it does not depend on the physical make up of the coil. Another factor which effects the magnetic strength of a coil is the number of turns in the coil. The word "turn" as used here refers to a loop of the conductor in the coil. The more turns on the coil the more magnetic strength the coil will have.

DO NOT MARK IN THIS TEXT.

Fill in the blanks with the correct word(s) on the response sheet.

1. If current flow is decreased through a coil, the magnetic strength of the coil will _____.

2. If two coils have the same amount of current flowing through them, then the one with five turns will have (more/less) _____ magnetic strength than the coil with two turns.

Answers to Frame 25: 1. decrease 2. more

Frame 26

The magnetic strength of a coil is also based on how close the turns in the coil are to each other. When the turns are relatively far apart, as shown below in part A of figure 20, many of the lines of force will circle one turn of the coil only. When the turns are close to each other as in B, a great many more lines of force will encircle the whole coil. Thus, coil B will have a stronger magnetic field than will coil A (assuming that both coils have the same amount of current flowing through them). The relationship between magnetic strength and turns in the coil can be summed up in the statement: "The greater the number of turns per inch in a coil, the greater its magnetic strength will be." The magnetic force of a coil, which is based on the turns per inch and the current in the coil, is called "magnetomotive force" and is equal to the current (in amperes) in the coil multiplied by the number of turns per inch.

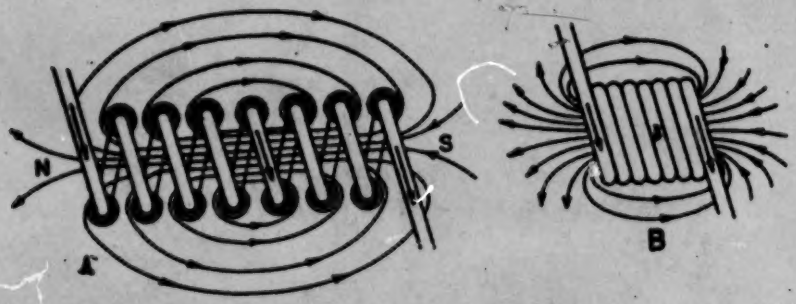


Figure 20.

DO NOT MARK IN THIS TEXT.

Fill in the blanks with the correct word(s) on the response sheet.

1. Magnetomotive force can be increased either by increasing the turns per inch in a coil or by increasing the _____ through it.

2. The number of turns per inch multiplied by the current (in amperes) is equal to the amount of _____ force in a coil.

Answers to Frame 26: 1. current 2. magnetomotive

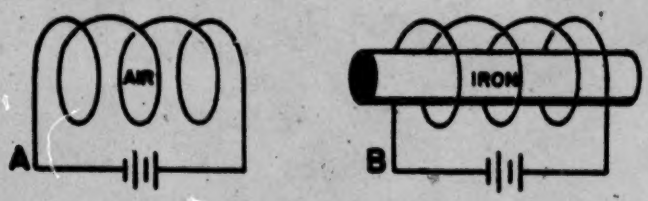
Frame 27

We have just seen that the magnetomotive force in a coil affects the magnetic strength of a coil. The kind of material in the core of a coil also affects the magnetic strength of a coil. If a soft iron bar is inserted into a coil, the magnetic strength of that coil will be increased tremendously. The reason for this is that the iron is much more permeable than air and therefore, more lines of force will flow through the iron. We stated earlier in this programmed text that air has a permeability of about 1.0 whereas soft iron has permeability of about 10,000. This means that the magnetomotive force necessary to produce one line of force inside a coil with an air core, will produce about 10,000 lines of force if a soft iron core is inserted into the coil. This is partly due to the fact that the iron core becomes magnetized and its magnetic field is added to the magnetic field of the coil.

DO NOT MARK IN THIS TEXT.

Choose one of the answers given and write its letter on the response sheet.

1. If the magnetomotive force in each of these coils is the same, the magnetic strength of coil _____ will be much greater.



2. Three factors mentioned in this programmed text which affect the magnetic strength of a coil are (circle the letter in front of the correct answer).

   a. permeability of the core, flux leakage, and current flow.

   b. permeability of the core, turns per inch, and current flow.

   c. current, voltage, and resistance.

Answers to Frame 27: 1. B 2. b

Frame 28

Reluctance is commonly defined as the opposition offered by a magnetic circuit (for instance a coil) to lines of force. The reluctance of the coil depends on the length of the core, the cross-sectional area of the core and the type of material of the core. The distinguishing traits of the reluctance of a coil are comparable to those of resistance in an electrical circuit. A substance such as hard steel will have more reluctance than will soft iron whereas soft iron has higher permeability than does hard steel. From this we can see that permeability and reluctance are opposites.

DO NOT MARK IN THIS TEXT.

Fill in the blanks with the correct word(s) on the response sheet.

1. The opposition offered by a magnetic circuit to lines of force is called _____.

2. Soft iron has (lower/higher) _____ reluctance than does hard steel.

402

Answers to Frame 28: 1. reluctance 2. lower

Frame 29

When current flow is increased, the magnetic strength of a coil will increase up to the point of saturation of the core material. At this point very little increase in magnetic strength will occur with a current increase. The amount of current that can flow through the coil is determined by the size of the wire in the coil, the number of turns, and the applied voltage.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

_____1. Magnetic strength will increase very rapidly at saturation.

_____2. As current increases through a coil, the magnetic strength will increase until saturation occurs.

_____3. Decreasing the current flow through a coil will cause the magnetic field to decrease.

408

Answers to Frame 29: ____1. __T__2. __T__3.

Frame 30

A current carrying coil which has a core of magnetic material is commonly called an electromagnet. Many electromagnets use iron cores due to the fact that iron is easily magnetized. Some electromagnets, such as the one in figure 21 below, are so large and powerful that they can lift tons of scrap metal at one time. Other electromagnets used in some electrical and electronic circuits are very small. Magnets commonly used can be classified as either permanent magnets or electromagnets (temporary).

Figure 21.

DO NOT MARK IN THIS TEXT.

Fill in the blanks with the correct word on the response sheet.

1. A coil which is wound on a core of magnetic material is called an _____.

2. Horseshoe magnets, bar magnets, compass needles, which work without electrical power, are all _____ magnets, while magnets which get their power from the current in a coil are _____.

3. Regardless of the sources of the fields around magnets, they all _____ the fundamental laws of magnetism.

Answers to Frame 30: 1. electromagnet 2. permanent electromagnets

3. obey

Frame 31

As stated earlier, electromagnets are used in many electrical devices such as circuit breakers, relays and micropositioners. You will study all of them in greater detail in a later lesson. However, let us take a closer look at the use of electromagnets in a meter used to measure current flow.

If an electromagnet is mounted on a pivot between the poles of a permanent magnet as in figure 22, as current flows through the coil, the poles of the electromagnet will be repelled by the poles of the permanent magnet. The more current that is flowing through the coil, the more the electromagnet will turn. If a needle is attached to the coil as in figure 23 below, and a calibrated scale is added, we can measure the amount of current flowing in the coil.

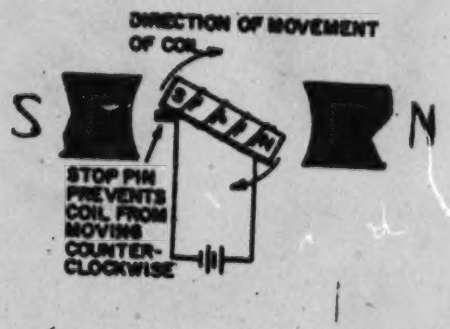


Figure 22.

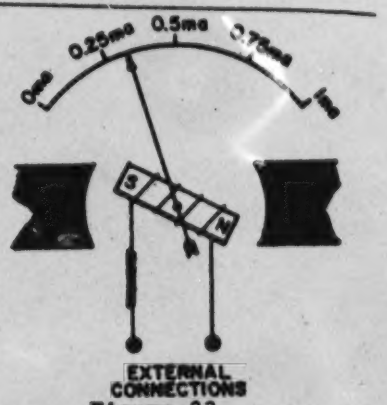


Figure 23.

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

_____1. In figure 22 the electromagnet is attracting the permanent magnet.

_____2. The coil in the meter movement in figure 22 can turn in either direction.

_____3. Electromagnets have many uses in electrical devices.

Answers to Frame 31: ____1. ____2. _T_3.

Frame 32

DO NOT MARK IN THIS TEXT.

Select those factor(s) that cause the magnetic strength of an electromagnet to increase by placing a checkmark in the blank provided on the response sheet.

____1. Decrease the number of turns of the coil.

____2. Decrease the distance between the turns of the coil.

____3. Decrease the current flow through the coil.

____4. Replace an air core with an iron core in the coil.

____5. Increase the distance between the turns of the coil.

____6. Increase the current flow through the coil.

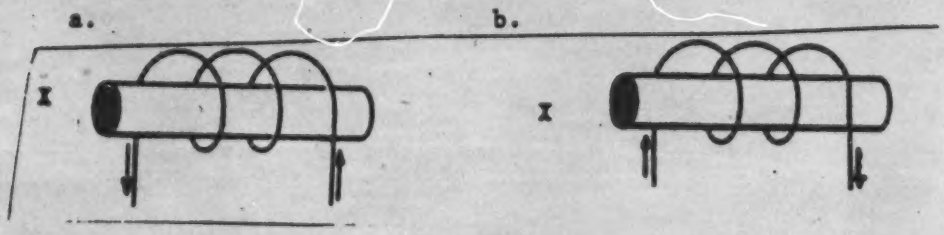
____7. Remove the iron core from the coil.

____8. Increase the number of turns of the coil.

Choose one of the answers given and write its letter on the response sheet.

9. Which coil has the north pole at point X?

a. b.



10. Which of the following would make the best magnetic shield?

a. Hard steel.

b. Soft iron.

c. Soft silver.

d. Alnico.

40b

Answers to Frame 32: ____1. __T__2. ____3. __T__4. ____5.
__T__6. ____7. __T__8. 9. b 10. b

Frame 33

DO NOT MARK IN THIS TEXT.

Mark the following true statements with a "T" on the response sheet.

____1. Soft iron is used to make temporary magnets.

____2. Permanent magnets retain their magnetism for long periods of time.

____3. Like magnetic poles will attract each other.

____4. Alnico is used in making permanent magnets.

____5. The space surrounding a magnet in which the magnetic force acts is called a magnetic field.

Select the statement(s) that correctly describe the magnetic lines of force by placing a checkmark in the blank provided on the response sheet.

____6. Are elastic and act as if under tension.

____7. Will cross at the poles.

____8. Will not pass through glass.

____9. Form continuous loops.

____10. Flow from south to north outside the magnet.

Fill in the blanks with the correct term on the response sheet. A list of terms is given below for you to use.

11. The measure of the ease with which a given material can conduct magnetic lines of force as compared to air is called _____.

12. The amount of magnetism retained by a substance after the magnetizing force is removed is called _____.

13. A highly permeable substance used to protect a delicate instrument from magnetic lines of force is called a _____.

14. The ability of a material to retain its magnetism is called _____.

Reluctance
Retentivity
Residual Magnetism
Permeability
Magnetic Shield
Magnetic Saturation

Frame 33 (Continued)

15. Point where the magnetic strength of a material will not increase with an increase in the magnetizing force is called _____.

16. The opposition offered by a magnetic circuit to lines of force is called _____.

Answers to Frame 33:

T 1.

T 2.

3.

T 4.

T 5.

T 6.

7.

8.

T 9.

10.

11. Permeability

12. Residual Magnetism

13. Magnetic Shield

14. Retentivity

15. Magnetic Saturation

16. Reluctance

PROGRAMMED TEXT

3ABR42331-PT- 109

Technical Training

Aircraft Environmental Systems Mechanic

DC GENERATION AND BASIC CIRCUIT SYMBOLS AND TERMS

19 August 1977

3350 TECHNICAL TRAINING WING
3370 Technical Training Group
Chanute Air Force Base, Illinois

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FOREWORD

This programmed text was prepared for use in the 3ABR42331 instructional system. The materials contained herein has been validated using students enrolled in the 3ABR42331 course. Ninety percent of the students taking this text have reached or surpassed the criterion called for in the approved lesson objective. The average student required 2 hours and 54 minutes to complete the text.

OBJECTIVES

1. Select basic facts, terms, and laws used in the generation of an electromagnetic field.

2. Select the basic symbols and terms used in electrical circuits.

Each of the above objectives will be accomplished with a minimum of 80% accuracy.

INSTRUCTIONS

Read each frame carefully beginning with the first frame. Answer the questions at the end of each frame in accordance with the instructions provided in the frame. Check your responses with the correct answers which are located on the top of the next frame. If you made an error, determine the cause and correct it before going on to the next frame. When you complete this lesson, contact your instructor for further instructions. Write all your answers on the response sheet. DO NOT MARK IN THIS TEXT!

OPR: 3370TTG
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3370TTGIC - 600; TIVSR - 1

Frame 1

The most complex electrical circuit can be reduced to a very basic circuit. Therefore, there is a great need for you to know all of the basic symbols in order to read these circuits. A basic circuit has five main parts each of which we will talk about as we move on into this lesson. These five main parts are the power source which supplied EMF to the load unit, conductor, protective device, and the controlling device.

Mark the following true statements with a "T" on the response sheet.

____ 1. Basic circuits are not meaningful to you.

____ 2. A basic circuit has five components.

____ 3. One of the components of a basic circuit is a power source which supplies EMF.

____ 4. One of the components of a basic circuit is a multimeter.

Answers to Frame 1: ____1. T 2. T 3. ____4.

Frame 2

First, let us talk about some common sources of EMF. In the lesson on electron theory we defined EMF as the force that will cause free electrons to move in a conductor (wire) from a negative potential to a positive potential. There are a lot of ways to generate voltage, but we are only going to talk about three of the more common types with which you will be dealing. They are chemical, mechanical, and heat.

Mark the following true statements with a "T" on the response sheet.

____ 1. EMF is the force that causes electron flow.

____ 2. There are only three methods of voltage generation.

____ 3. A source of EMF is needed for current flow.

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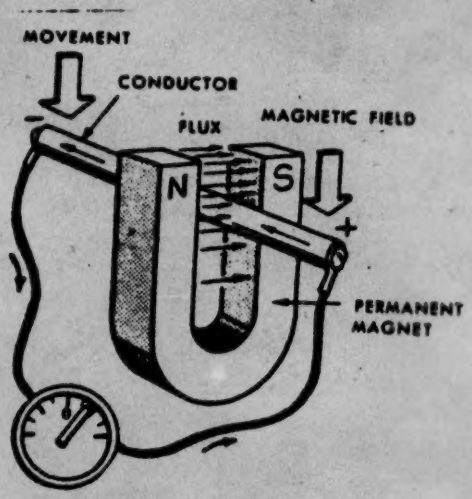
Answers to Frame 2: T 1. ____ 2. T 3.

Frame 3

First of all we will look at the mechanical method that is used to make an EMF. In this method a device is used that will change mechanical energy to electrical energy. The generator that we will find on our cars and on an aircraft and those that supply power to our homes are examples of this device. As the generator is turned, the conductors on the inside are moved through (cut) magnetic lines of force, this will induce a voltage in the conductor.



The above sketch shows this type of voltage generation in one of the simpler ways. You can see that the magnetic field is made by a "U" shaped permanent magnet. The conductor is hooked to a meter that acts as a load. Mechanical energy of some sort is used to move the conductor through the magnetic field. This will induce a voltage in the conductor. The voltage will flow through the wires and meter connected to the conductor and the meter will show the amount of induced voltage.

Mark the following true statements with a "T" on the response sheet.

____ 1. A generator changes electrical energy to mechanical energy.

____ 2. Voltage can be produced by moving a conductor so that it cuts magnetic lines of force.

____ 3. The energy used to operate the electrical units on the aircraft is energy that has been changed from mechanical energy supplied by the engines.

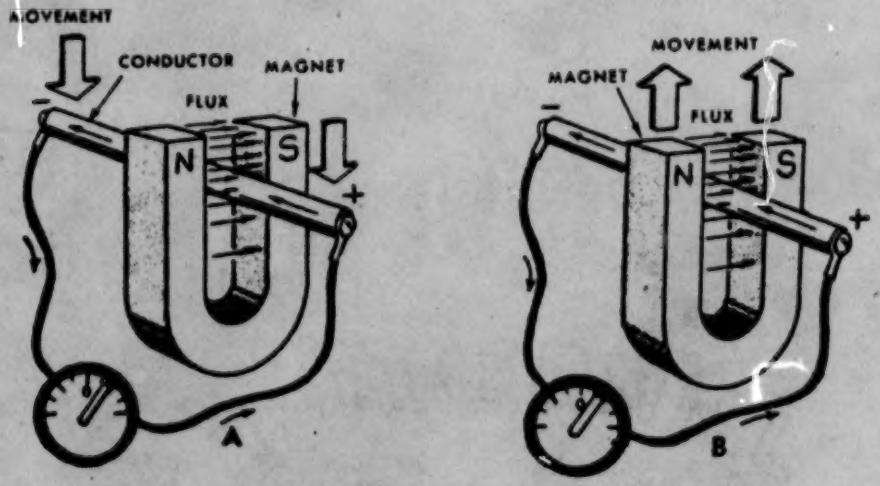
____ 4. The generator is one of the LEAST used devices for generating or producing voltage.

Answers to Frame 3: ____1. __T__2. __T__3. ____4.

Frame 4

In sketch "A" you can see that the "U" shaped magnet does not move but that the conductor does move down. In sketch "B" note that the magnet moves up and the conductor does not move. From these sketches it is easy to see that the outcome is the same; a voltage was induced in the conductor. A voltage will be made any time a conductor moves through magnetic lines of force.

The conductor must move across (not parallel to) the lines of force in order for it to "cut" these lines of force. A relationship will exist between the motion of the conductor and the angle at which it cuts the lines of force. This relationship is called relative angular motion. It can be said that when there is relative angular motion between a conductor and a magnetic field a voltage will be induced in that conductor. This is called electromagnetic induction. Electromagnetic induction is the principle of operation of all generators.



Mark the following true statements with a "T" on the response sheet.

____ 1. Voltage is induced in a conductor when both the conductor and the magnetic field are moved in the same direction at the same rate of speed.

____ 2. If there is relative angular motion between a conductor and a magnetic field, electromagnetic induction will take place.

____ 3. The motion required for voltage generation may be provided by moving either the conductor or the field.

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Answers to Frame 4: ____1. __T__2. __T__3.

Frame 5

You have now learned how to produce voltage by the mechanical method; now let us see how voltage can go up and down. This is done by increasing the speed of the relative angular motion between the conductor and the magnetic field. This means that the conductor will cut more lines of force in a given time which will cause the induced voltage to go up. Making the strength of the field go up means there will be more lines of force for a given area. If the magnetic field was to go up, and speed stay the same, the conductor would cut more lines of force in a given time, and the induced voltage would go up. Another way of making the voltage produced go up, is to add more conductors. When a conductor is wound to form a coil (as thread on a spool), there will be more conductors to cut the lines of force. Since the turns of the wire are in the same direction, the voltages are additive, and the total induced voltage will go up.

Mark the following true statements with a "T" on the response sheet.

____ 1. Increasing the speed of the relative angular motion between a conductor and a magnetic field decreases induced voltage.

____ 2. Decreasing the strength of the magnetic field through which a conductor cuts the lines of force decreases voltage induced in the conductor.

____ 3. Increasing the number of turns in a conductor cutting magnetic lines of force decreases induced voltage in the conductor.

____ 4. Speed, strength of the magnetic field, and the number of turns of the conductor are three factors which affect the amount of voltage induced in the conductor by electromagnetic induction.

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Answers to Frame 5: ____1. __T__2. ____3. __T__4.

Frame 6

The next way of producing a voltage is by the chemical method. The battery in a car, or the cell in a flashlight are examples of voltage generation by the chemical method. If any two metals, which are not the same, are put in a solution that will conduct electricity, a voltage is produced. The metals are referred to as plates. The solution in which the plates are put is called electrolyte. If a plate of copper, and a plate of aluminum are put in a container of drinking water, a voltage is produced. In the sketch below, note the deflection of the needle on the meter which is hooked up to the copper and aluminum plates in the drinking water.

Mark the following true statements with a "T" on the response sheet.

____ 1. Two like metals immersed in an electrolyte produce a voltage.

____ 2. The voltage produced by immersing copper and aluminum in drinking water is produced by the chemical method.

____ 3. Copper and iron plates immersed in drinking water produce a voltage.

____ 4. The materials immersed in electrolyte to produce voltage are called plates.

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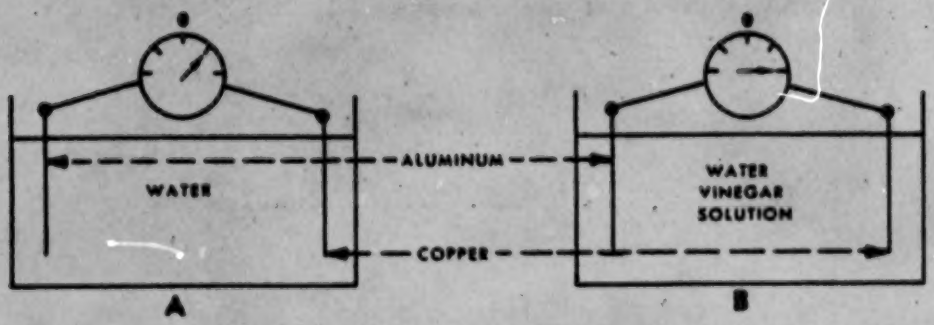
Answers to Frame 6: ____1. __T__2. __T__3. __T__4.

Frame 7

Since you know how voltage can be produced by the chemical method, let us find out how the voltage can be raised or lowered. One way to do this is to use a different electrolyte. A and B in the sketch below are identical except for the electrolyte. The one on the left uses drinking water as the electrolyte, and the other one uses a solution of vinegar and water as the electrolyte. Note that the vinegar and water solution will make a greater needle deflection on the meter. This will tell you that a higher voltage is produced.



Mark the following true statements with a "T" on the response sheet.

____ 1. If the same two unlike metals are immersed in a different kind of electrolyte, the same amount of voltage is produced.

____ 2. In the above illustration, voltage is being produced by the chemical method.

____ 3. The meters in the illustration indicate that a higher voltage is produced with the electrolyte of vinegar and water solution than with drinking water.

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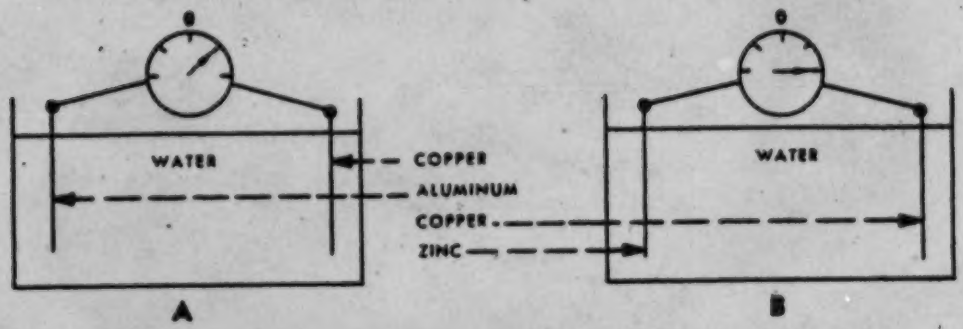
Answers to Frame 7: ____1. __T__2. __T__3.

Frame 8

We have found that the same combination of metals when put in different types of electrolyte will produce different amounts of voltage. By using different combinations of metal plates in the same electrolyte we can also produce different amounts of voltage. In the sketch below, A and B are identical, except that a different combination of metals have been put in the electrolyte. Note that the voltage produced by the copper plates and the zinc plates is much higher than the voltage produced by the copper plates and the aluminum plates.



Mark the following true statements with a "T" on the response sheet.

____ 1. Copper and aluminum immersed in water produce a higher voltage than copper and zinc immersed in water.

____ 2. Voltage produced by the chemical method can be varied by either using different types of metals, or by the use of different types of electrolyte.

____ 3. In the above illustration, voltage is produced by the mechanical method.

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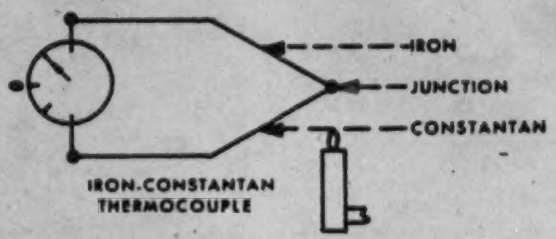
Answers to Frame 8: ____1. T 2. ____3.

Frame 9

Even though the mechanical and chemical methods are used to produce most of our electrical power, the thermal or heat method of voltage generation also has its uses. This method is used in heat indicating circuits and fire warning systems. The device that is used to produce the voltage is called a thermocouple. In this method when two wires of unlike metals are joined at one end, and heat is put on the junction of these wires, a voltage will be produced. In the sketch shown, one wire is iron, and the other wire is constantan (an alloy of nickel and copper). Heat is applied to the junction (the point at which the two wires are joined together), and the meter that is hooked up to the thermocouple shows that a voltage is generated.



Mark the following true statements with a "T" on the response sheet.

____ 1. A thermocouple is a device used to produce voltage by the heat or thermal method.

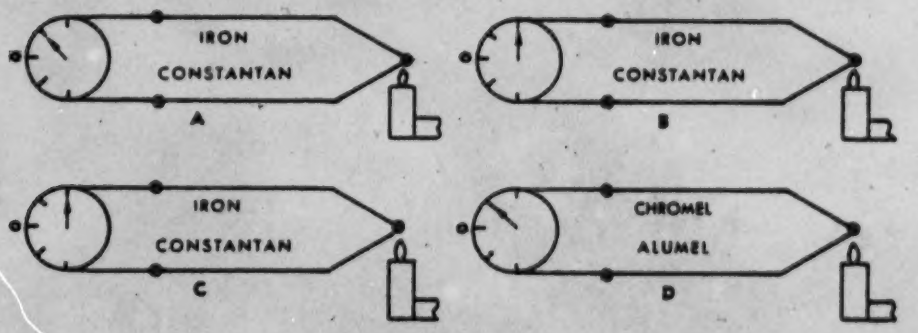
____ 2. The chemical method of producing voltage, changes heat energy to electrical energy.

____ 3. If two dissimilar metal wires joined at one end are heated at their junction, a voltage is generated.

Answers to Frame 9: T 1. ____2. T 3.

Frame 10

The voltage made by the thermal method can be changed in two different ways. If the heat is changed, the amount of voltage generated will change. This is why the thermocouple can be used in heat indicating circuits. As the heat goes up, the voltage goes up. As shown in the sketch, a meter can be hooked between the ends of the thermocouple and must be marked in degrees to show the temperature at the thermocouple junction. The other means of getting a different voltage is to use two different metals in the wires. In the sketch shown, A and B are the same thermocouples, but more heat is put on B than is put on A, and the voltage generated by B is higher. C and D are made of different metals. The same amount of heat is put on each, but the iron-constantan thermocouple generates a higher voltage than the chromel-alumel thermocouple.



Mark the following true statement(s) with a "T" on the response sheet.

____ 1. Different metals in thermocouples produce different amount of voltage.

____ 2. Increasing the amount of heat applied to a thermocouple increases the amount of voltage generated.

____ 3. In the illustration, voltage is produced by the chemical method.

____ 4. The thermocouple is used to produce voltage by the mechanical method.

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Answers to Frame 10: T 1. T 2. ____3. ____4.

Frame 11

Match the definitions on the right to the terms on the left. Be sure to distinguish between the device or example and the method. Write your answer on the response sheet.

____	1.	Mechanical method	a. Device that uses mechanical energy to produce an EMF.
____	2.	Battery	b. Voltage is produced by two dissimilar metals immersed in a solution which will conduct electricity.
____	3.	Generator	c. Voltage is produced by relative angular motion between conductors, and a magnetic field.
____	4.	Heat or thermal method	d. Device that uses heat to produce an EMF.
____	5.	Thermocouple	e. Example of the chemical method.
____	6.	Chemical method	f. Voltage is produced when heat is applied to two dissimilar metals which are joined at one end.

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Answers to Frame 11: c 1. e 2. a 3. f 4. d 5. b 6.

Frame 12

By now you should understand that the first part of a basic circuit is the powersource which supplies EMF. Examples of a power source are a battery, generator, and thermocouple. In frame 1, we said that there was a need to know basic symbols in order to trace out the circuits. Symbols are used to make identification of units easier, and to remove thy need for writing the name or drawing a picture of the unit. The schematic symbols for a battery, generator, and thermocouple are shown below.

NOTE: Short line is negative, long line is positive.

Draw the correct symbol by its term on the response sheet.

1. Thermocouple _____.

2. Battery _____.

3. Generator _____.

Answers to frame 12. 1. 2. 3.

Frame 13

The second part of a basic circuit is the load unit. This is a device which needs current to perform a task. Some examples are lamps, motors, resistors, and coils. For now, we will be concerned mainly with lamps and resistors.

Mark the following true statements with a "T" on the response sheet.

____ 1. A load unit performs its function by using current.

____ 2. A motor is an example of a load unit.

____ 3. A thermocouple is an example of a source of EMF.

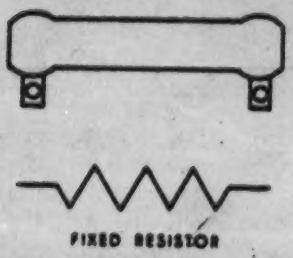
____ 4. A resistor is a source of EMF.

____ 5. A lamp is a protective device.

Answers to Frame 13: T 1. T 2. T 3. ___4. ___5.

Frame 14

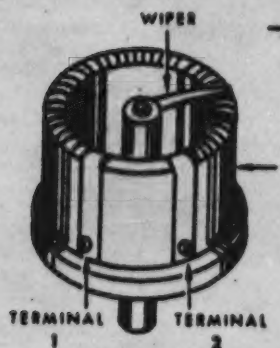
Some examples of load units and their symbols are shown below:



FIXED RESISTOR

SYMBOL FOR A RHEOSTAT OR A VARIABLE RESISTOR

LAMP



COLORED LAMPS ARE DESIGNATED AS FOLLOWS:

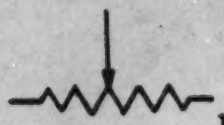
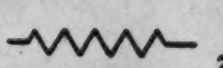
Draw the correct symbols beside their terms on the response sheet.

1. Variable resistor or rheostat _____

2. Fixed resistor _____

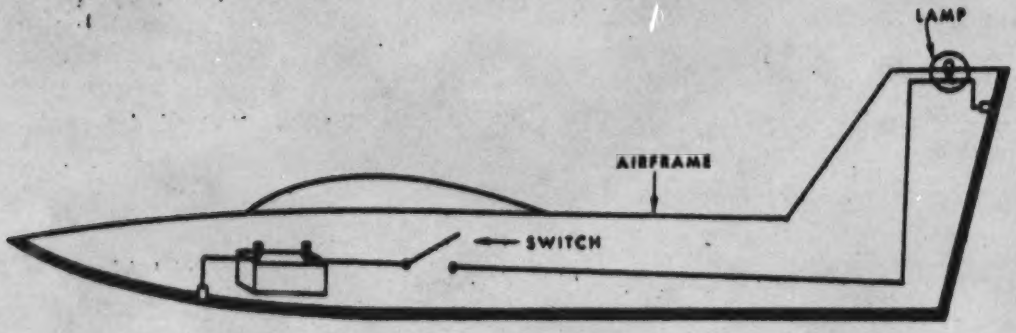
3. Lamp _____

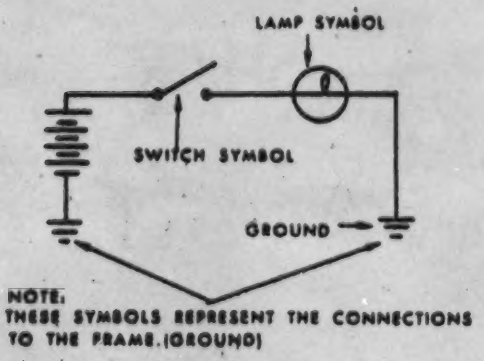
4. Clear lamp _____

Answers to frame 14.  1.  2. 3. 4.

Frame 15

A third part of a basic circuit is a conductor. This is the part that is used to form the path that current will follow. A wire is the most common kind of a conductor used. The schematic symbol for a wire is a solid line. The metal frame of the aircraft can also be used as a conductor (wire). To simplify a circuit, the metal frame is used as one of the paths for electron flow. This mode will also cut down the weight of the aircraft by cutting down the amount of wiring the aircraft mus have. When the switch in the sketch below is closed the circuit is completed. Electrons will flow from the battery to the aircraft frame, through the frame to the lamp ground wire, and on to the lamp. From the lamp they move on through the wire; to and through the switch to the battery. A schematic diagram of this is shown below.





Mark the following true statements with a "T" on the response sheet.

___ 1. is a ground connection symbol.

Frame 15 Cont'd

____ 2. The aircraft structure is used as a conductor.

____ 3. A wire is the only conductor used in the aircraft.

____ 4. The case of some units is used as a conductor.

Answers to Frame 15: T 1. T 2. ___3. T 4.

Frame 16

Below are the symbols widely used to indicate connection or no connection of conductors.

1. Crossing (no connection.)

2. Connection.

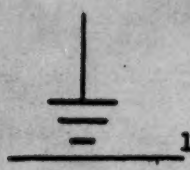
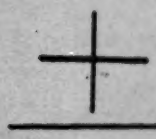
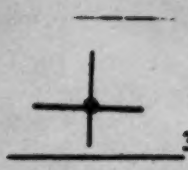
3. Ground connection.

Draw the correct symbol beside its name on the response sheet.

1. Ground connection _____.

2. Crossing (no connection) _____.

3. Connection _____.

Answers to frame 16.  1.  2.  3.

Frame 17

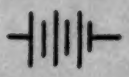
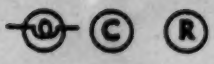
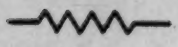
Let's check to see how much you have learned.

I. Match the terms on the right with the components on the left. Some terms will be used more than once. Write your answers on the response sheet.

____	1.	Motor	a. Load unit
____	2.	Battery	b. Conductor
____	3.	Wire	c. Source of EMF.
____	4.	Resistor	
____	5.	Thermocouple	
____	6.	Aircraft structure	
____	7.	Case of a unit	
____	8.	Generator	
____	9.	Lamp	

Frame 17 (Cont'd)

II. Match the terms on the right with the symbols on the left. Write your answers on the response sheet.

___ 1.		a.	Generator
___ 2.		b.	Lamps
___ 3.		c.	Thermocouple
___ 4.		d.	Variable resistor
___ 5.		e.	Conductors connected
___ 6.		f.	Ground
___ 7.		g.	Resistor fixed
___ 8.		h.	Battery
___ 9.		i.	Conductors crossing (no connection)

If you missed any of the above, review the appropriate frame before proceeding with frame 18.

If you got them all correct, proceed with frame 18.

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Answers to Frame 17:

Section I: a 1. c 2. b 3. a 4. c 5. b 6. b 7. c 8. a 9.

Section II: h 1. c 2. i 3. b 4. g 5. a 6. f 7. e 8. d 9.

Frame 18

So far we have gone over three parts of a basic circuit. We have two more parts left, a controlling device and a protective device. The controlling device is used to turn the circuit ON and OFF. Switches and relays are used for this purpose. The relay is used as a remote control type of switch. You have used a switch each time you turned your room light on and off. There are a lot of different types of switches and relays that will be gone over in a later lesson. For the present, remember that relays and switches are controlling devices. Shown here is the symbol for a basic switch.

Mark the following true statements with a "T" on the response sheet.

____ 1. The relay is the only controlling device that you will use.

____ 2. The symbol for a switch is .

____ 3. A controlling device is used to turn a circuit ON and OFF.

____ 4. A switch is a controlling device.

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Answers to Frame 18: ___1. _T_2. _T_3. _T_4.

Frame 19

To close a switch means to turn the switch to a position which will allow current to flow through it. Thus, to open a switch means to turn the switch to a position which will no allow current to flow through it.

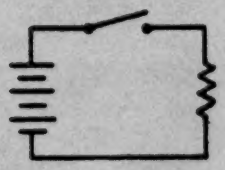


Figure 1.

In figure 1 we have a source of EMF (power), conductor, load unit, and a controlling device. Note that the switch is open. Thus, we have a circuit which will not have a complete path for current flow. Now if we close the switch, as in figure 2, we will have a complete path for current to flow to the load.

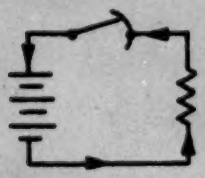


Figure 2.

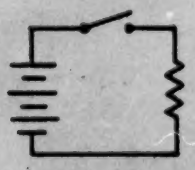


Figure 3.

Mark the following true statements with a "T" on the response sheet.

____ 1. In figure 3, there is a complete path for current flow.

____ 2. In figure 3, if the switch is closed there will be a complete path for current flow.

____ 3. Figure 3 shows a complete circuit of a switch, conductor, resistor, and a <u>generator</u>.

Answers to Frame 19: ___1. _T_2. ___3.

Frame 20

The fifth and last part of a basic circuit is a protective device. It is used to protect the circuit against too high a current flow. Two examples of protective devices are fuses and circuit breakers. The main difference between the two is that a circuit breaker can be reset and reused, while a fuse cannot and must be replaced if blown. There are many types of fuses and circuit breakers. You will study these in a later lesson.

The basic symbol for a fuse is . The symbol for one type of circuit breaker, the push-pull is .

Mark the following true statements with a "T" on the response sheet.

____ 1. The symbol for a fuse is .

____ 2. A fuse can be reset.

____ 3. The symbol for a push-pull circuit breaker is .

____ 4. A protective device protects the circuit from an under-voltage condition.

____ 5. Fuses and circuit breakers are protective devices.

Answers to Frame 20: _T_1. ___2. _T_3. ___4. _T_5.

Frame 21

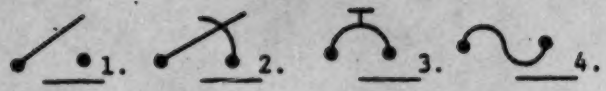
Draw the correct symbol beside its name on the response sheet.

1. Switch open _____.

2. Switch closed _____.

3. Push-pull circuit breaker _____.

4. Fuse _____.

Answers to frame 21.  1. 2. 3. 4.

Frame 22

In the lesson you had on Electron Theory EMF, Current, and Resistance was defined. In this frame we will review the definitions of EMF and current and add some other facts you need to know about them.

EMF is the force that is needed to cause current to flow. EMF is the abbreviation for electromotive force. There are other terms which have almost the same meanings, like voltage, potential difference, and electrical pressure. The symbol we use for all these terms is E. The unit of measurement of EMF is the volt. One volt is the pressure that is required to send one ampere of current through a resistance of one ohm. The symbol for volt is V.

Current was defined as the flow of electrons through a conductor from a negative potential to a positive potential. Again it must be said that there are terms that have just about the same meaning as current. These are electron flow, intensity, and amperage. The symbol for all these terms is I. The unit of measurement for current is the ampere. The symbol for ampere is a.

Place the symbol in the blank space on the response sheet for each of the following terms.

_____ 1. electromotive force

_____ 2. current

_____ 3. volt

_____ 4. potential difference

_____ 5. ampere

_____ 6. voltage

Answers to Frame 22: E 1. I 2. V 3. E 4. a 5. E 6.

Frame 23

Resistance is the opposition to current flow in a dc circuit. The symbol for resistance is R. The unit of measurement of resistance is the ohm. One ohm is the value of resistance through which 1 ampere of current will flow when one volt is applied to it. The symbol for ohm is the Greek letter omega, written as Ω.

Mark the following true statements with a "T" on the response sheet.

____ I. Resistance is the opposition to current flow in a DC circuit.

____ 2. The symbol for resistance is Ω.

____ 3. The unit of measurement for resistance is omega.

____ 4. The symbol for ohm is Ω.

Answers to Frame 23: T 1. ___2. ___3. T 4.

Frame 24

Match the symbols on the right with the terms on the left and write the answers on the response sheet.

____1.	Volt	a.	E
____2.	Ohm	b.	V
____3.	Resistance	c.	R
____4.	Current	d.	a
____5.	Ampere	e.	Ω
____6.	Voltage	f.	I

If you miss any of these, restudy frames 22 - 23 before proceeding to frame 25.

If you got these all correct, proceed to frame 25.

Answers to Frame 24: b 1. e 2. c 3. f 4. d 5. a 6.

Frame 25

The amount of voltage, current, and resistance in a circuit is based on the type of circuit. For measuring these values we use meters. To measure current flow we use an ammeter, to measure potential difference we use a voltmeter, and to measure resistance, we use an ohmmeter. The use of these meters will be the topic of another lesson. For now we are concerned only with the symbols for these meters. They are as follows:

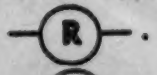
1. Ammeter

2. Voltmeter

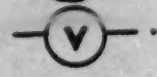
3. Ohmmeter

Mark the following true statements with a "T" on the response sheet.

____ 1. An ohmmeter is used to measure current flow in a circuit.

____ 2. The symbol for the ohmmeter is 

.

____ 3. The symbol for the voltmeter is 

.

____ 4. The symbol for the ammeter is

.

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Answers to Frame 25: ___1. ___2. _T_3. _T_4.

Frame 26

Now let's combine some of the symbols you have learned and draw a basic circuit.

Now you will draw a basic circuit on the response sheet with a battery, conductor, circuit breaker, switch, and a lamp, not a resistor as shown above.

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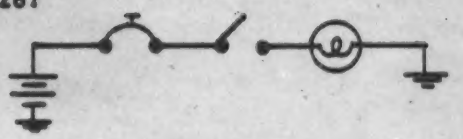
Answer to Frame 26:



Frame 27

Match the terms on the right with the components on the left. The terms can be used more than once. Write your answers on the response sheet.

_____1. Wire	a. Load unit
_____2. Aircraft structure	b. Source of EMF
_____3. Resistor	c. Conductor
_____4. Relay	d. Protective device
_____5. Motor	e. Controlling device
_____6. Lamp	
_____7. Switch	
_____8. Case of unit	
_____9. Generator	
____10. Thermocouple	
____11. Fuse	
____12. Battery	
____13. Circuit breaker	

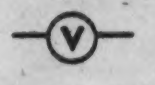
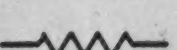
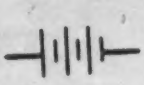
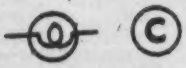
If you missed any of these, restudy the appropriate frame dealing with the question or questions you missed before proceeding with frame 28.

If you got these all correct, proceed with frame 28.

Answers to Frame 27: c 1. c 2. a 3. a 4. a 5. a 6. a 7.
c 8. b 9. b 10. d 11. b 12. d 13.

Frame 28

Match the terms on the left with the symbols on the right. Write your answers on the response sheet.

____1. Generator	a. Ω	o. 
____2. Thermocouple	b. a	
____3. Volt	c. V	p. 
____4. Variable resistor	d. R	
____5. Ammeter	e. E	q.
____6. Ground	f. I	
____7. Fixed resistor	g.	r.
____8. Voltage		
____9. Battery	h.	s.
____10. Ohmmeter		
____11. Resistance	i.	t.
____12. Lamps		
____13. Current	j.	u.
____14. Ohm		
____15. Voltmeter	k. 	
____16. Conductors connected	l. 	
____17. Ampere		
____18. Circuit breaker		
____19. Conductors crossing	m.	
____20. Switch		
____21. Fuse	n.	

If you missed any of these, restudy the frame covering that symbol or symbols before proceeding to frame 29.

Answers to Frame 28: i 1. i 2. c 3. m 4. n 5. u 6. p 7.
e 8. k 9. q 10. d 11. l 12. f 13. a 14.
o 15. t 16. b 17. 6 18. s 19. r 20. h 21.

Frame 29

Match the definitions on the right to the terms on the left. Be sure to distinguish between the device or example and the method.

_____1. Chemical method
_____2. Thermocouple
_____3. Generator
_____4. Heat or thermal method
_____5. Battery
_____6. Mechanical method

a. Device that uses mechanical energy to produce an EMF.
b. Voltage is produced by two dissimilar metals immersed in a solution that will conduct electricity.
c. Voltage is produced by relative angular motion between conductors and a magnetic field.
d. Device that uses heat to produce an EMF.
e. Example of the chemical method of producing an EMF.
f. Voltage is produced when heat is applied to two dissimilar metals which are joined at one end.

If you missed any of these, restudy frames 2 - 11.

Answers to Frame 29: b 1. d 2. a 3. f 4. e 5. c 6.

PROGRAMMED TEXT

3ABR42331-PT-110

Technical Training

Aircraft Environmental Systems Mechanic

WIRING DIAGRAM FUNDAMENTALS

25 January 1979

CHANUTE TECHNICAL TRAINING CENTER (ATC)
3370 Technical Training Group
Chanute Air Force Base, Illinois

Designed for ATC Course Use.

Do Not Use on the Job.

FOREWORD

This programmed text was prepared for use in the 3ABR42331 instructional system. The material contained herein has been validated using 30 students enrolled in the 3ABR42331 course. Ninety perfent of the students taking this text surpassed the criterion called for in the approved lesson objective. The average student called for in the approved lesson objective. The average student required three hours to complete the text.

OBJECTIVES

Select five (5) of the six (6) elements that make up the wire numbering system.

Select common symbols of wiring diagrams, with a minimum of 80% accuracy.

INSTRUCTIONS

This programmed text presents information in small steps called "frames." Read the material presented, select your response(s) at the end of the frame as required. Do not mark in the text. Enter your response(s) on the response sheet provided. After you have made your selections check your work against the answers on the following page. If your selections were correct, go on to the next frame and repeat the above process. If you have made an incorrect response, reread the frame until you understand your error and/or see your instructor. After you complete the text and response sheet see your instructor for the appraisal test.

Supersedes 3ABR42331-PT-117, 14 August 1972.
OPR: 3370 TCHTG
DISTRIBUTION: X
3370 TCHTG/TTGU-P - 400; TTVSA - 1

Frame 1

Many miles of electrical wire are used to connect the various units into operational systems. These wires are the connecting links between the source of power and the unit requiring power. By placing a number of these wires, units, and circuits together a wiring diagram is formed. As a mechanic, you will be called upon to use and interpret these wiring diagrams; that is, identify the symbols used, identify the wires, and trace the electrical systems. Wiring diagrams can help you gain an understanding of how the system works. Wiring diagrams are also a valuable aid in troubleshooting the electrically operated portions of the numerous systems that make up the aircraft control systems.

Place the letter T beside each of the following true statements.

_____1. Training on the proper use and interpretation of wiring diagrams is important to you because you will have to check aircraft circuits.

_____2. A wiring diagram on an aircraft air conditioning system will help you troubleshoot the system.

_____3. To be able to use a wiring diagram efficiently you must be able to identify the symbols, identify the wire, and trace a wire that is used to operate a unit.

Answers to Frame 1: 1. T 2. T 3. T

Frame 2

Some AN connectors are shown below in illustration #1. They are used where an electrical unit must be removed and reinstalled easily and quickly. These connectors consist basically of a plug, a receptacle, and a coupling nut which holds the unit together. Both the plug and receptacle consist of an aluminum shell containing an insulated insert which holds the contact points. The symbols shown in illustration #2 below are used on electrical wiring diagrams to illustrate the AN connectors. The symbols in illustration 2A and 2B are used on some diagrams to illustrate the plug and receptacle on some connectors. The symbol shown in illustration 2C is also used to illustrate the plug and receptacle of these connectors. The letter in front of each connector number denotes whether it is a plug or receptacle, P standing for plug and J standing for receptacle.

ILLUSTRATION #1

ILLUSTRATION #2

Place the letter T beside each of the following true statements.

_____1. Symbols are used on wiring diagrams to indicate the components required in the electrical system.

_____2. In connector number P159, the letter P indicates that this section of the connector is a receptacle.

_____3. Connector plugs and receptacles are used where an electrical unit must be removed and reinstalled easily and quickly.

Answers to Frame 2: 1. T 2. F 3. T

Frame 3

A terminal block (strip) and terminal are shown below in illustration 1. There is a single row of terminal posts (studs) set in some insulating material. This is shown in illustration #2. Terminal strips are used to connect wires going to one unit and to parallel electrical circuits when one source of power is used for more than one circuit. The symbol for a terminal block (strip) is shown in illustration 2. Terminal block (strips) are usually located in an enclosed distribution box called a Junction Box.

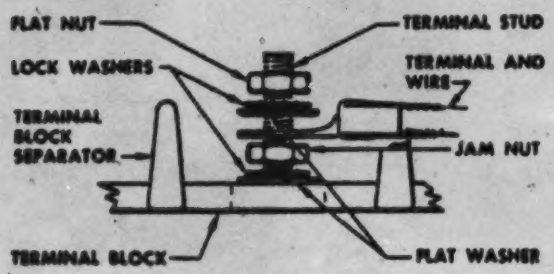


Illustration #1

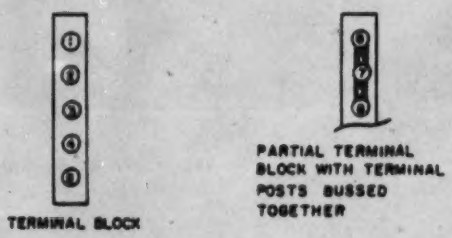


ILLUSTRATION #2

Place the letter T beside each of the following true statements.

_____1. Terminal blocks (strips) are used where an electrical unit must be removed and reinstalled easily and quickly.

_____2. The terminal posts on a terminal strip can be bussed (connected) together.

_____3. A terminal block (strip) is a single row of studs mounted in a terminal block which is made of some insulating material.

Answers to Frame 3: 1. F 2. T 3. T

Frame 4

The symbols shown in the illustration below are used on wiring diagrams to indicate the conductors. The symbol for the cable assembly indicates the wires that are bound together in the same wiring harness or bundle. Some bundles may be as thick as a man's arm while others may be made up of only two cables. Wire bundles are used throughout the aircraft to minimize battle damage and to speed manufacturing of the aircraft.

Place the letter T beside each of the following statements that are true.

_____ 1. As little as two wires can be used to make up a wire bundle.

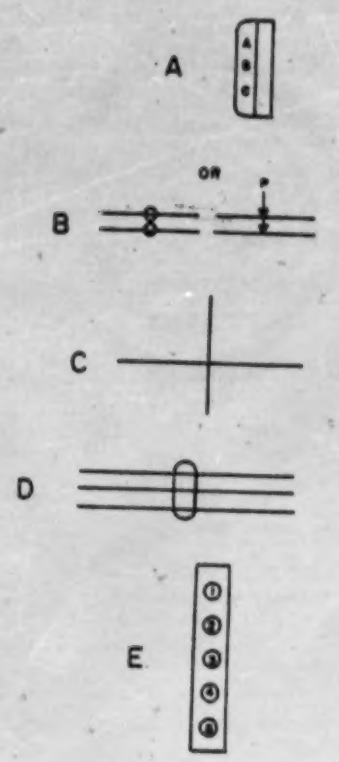
_____ 2. Two conductors can be twisted together.

Answers to Frame 4: 1. T 2. T

Frame 5

Match the symbols in column B with the identifying name for that symbol in column A.

Column A		Column B
_____1.	Crossing paths conductors	
_____2.	Twisted conductors	
_____3.	Terminal block	
_____4.	AN connector	
_____5.	Cable assembly	



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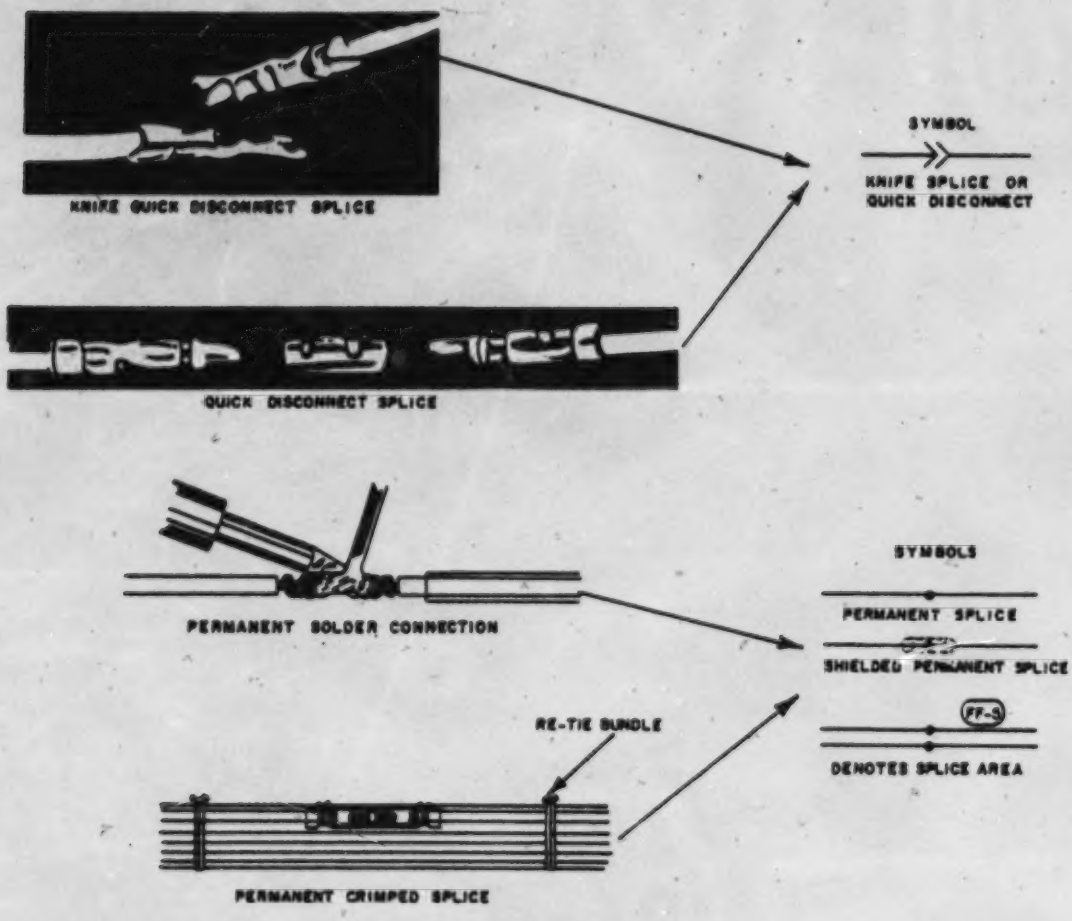
Answers to Frame 5: 1. C 2. B 3. E 4. A 5. D

Frame 6

A cable splice is a means of joining two pieces of cable together. The splice can be a permanent or quick disconnect type. The solder splice and the crimped splice can be used to repair a broken wire. The illustration below shows the different types of splices and the symbols that are used for them.



1. Draw the symbol used for a knife splice.

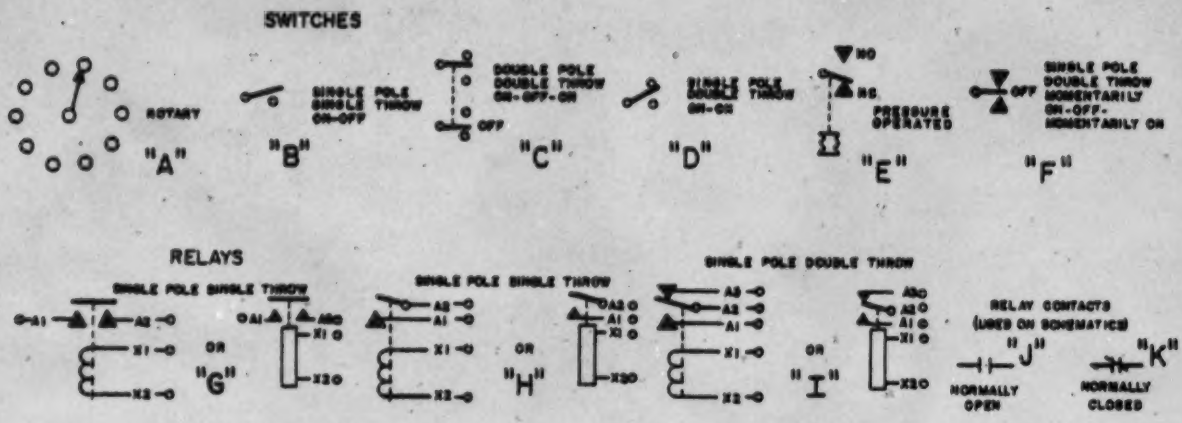
2. Draw the symbol used for a permanent splice.

Answers to Frame 6: 1. ——→ 2. ——●——

Frame 7

Symbols are used to represent the various types of switches and relays that control the electrical circuit operation. These symbols are shown in the illustration below. The relays are shown in the de-energized position. When the relay is energized, the armature of the relay (heavy black line connected to the dashed line) will move down. The symbols shown for the relay contacts are used on schematic diagrams and are being used more extensively. These symbols make it easier for you to follow the path of current flow through an electrical circuit.

Note: See instructor for display 9.



Match a letter from the illustration above to each of the statements below.

_____1. A switch that can be used to turn one circuit on or off.

_____2. A switch requiring one source of power capable of turning either one of two electrical circuits on and off.

_____3. A relay that can control two electrical circuits.

_____4. A normally open relay contact.

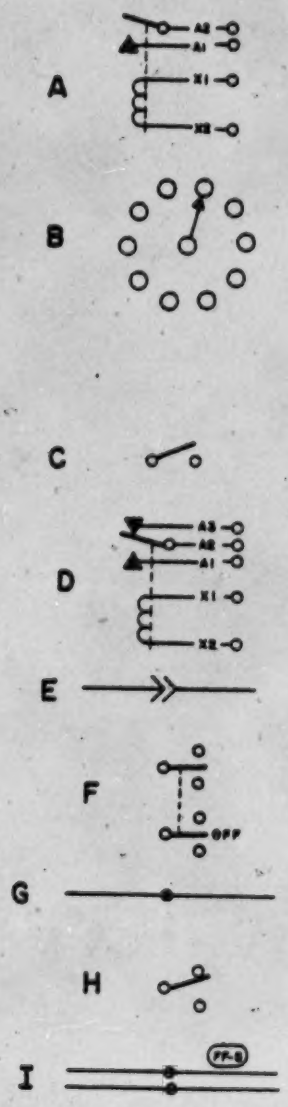
_____5. A switch that can control ten electrical circuits.

Answers to Frame 7: 1. B 2. D 3. I 4. J 5. A

Frame 8

Place the letter of the symbol from column B beside the correct name for that symbol in column A.

Column A		Column B
_____1.	Splice area	
_____2.	Rotary switch	
_____3.	Single pole double throw relay	
_____4.	Knife splice or quick disconnect	
_____5.	Single pole single throw relay	
_____6.	Single pole single throw switch	
_____7.	Single pole double throw switch	
_____8.	Double pole double throw switch	
_____9.	Permanent splice	



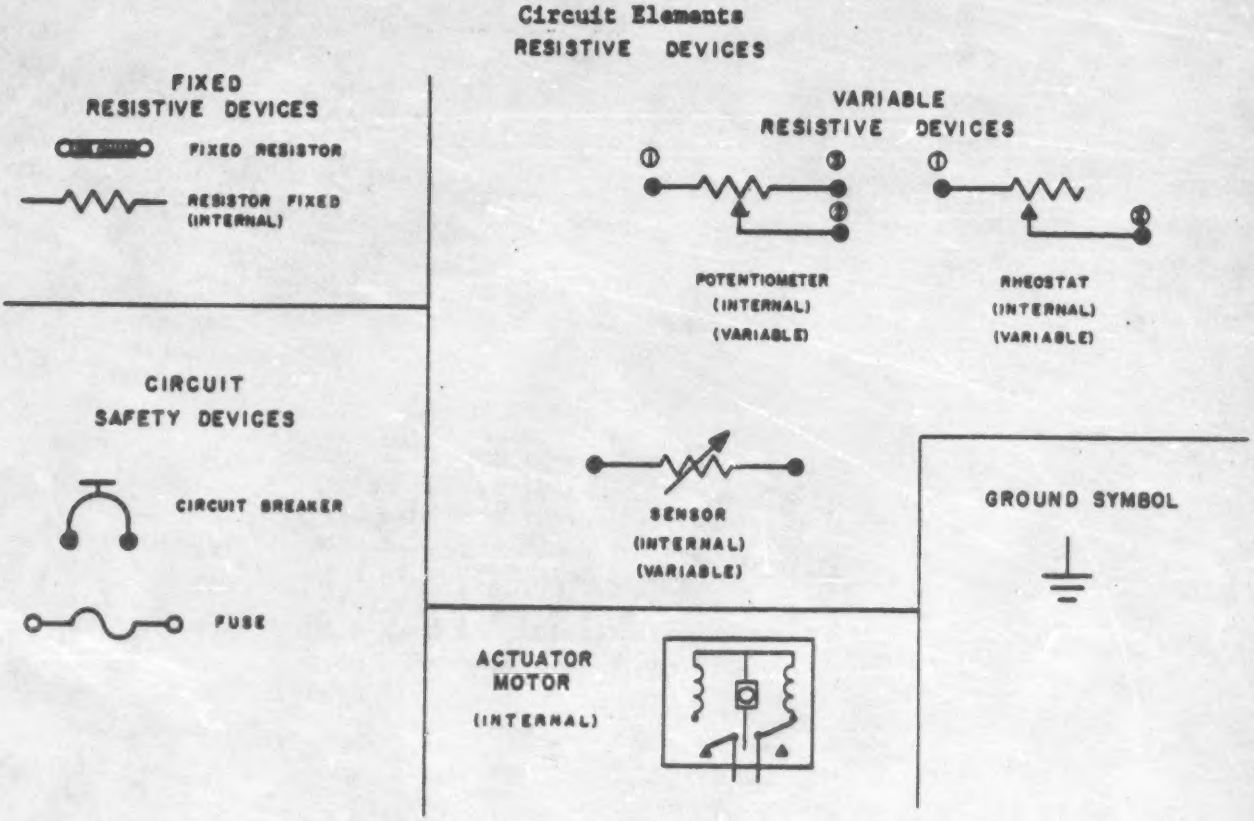
Answers to Frame 8: 1. J 2. B 3. D 4. E 5. A

6. C 7. H 8. F 9. G

Frame 9

The illustration below shows some of the other symbols you will see as you look at a wiring diagram. Becoming familiar with these symbols will help you read a wiring diagram.

Note: See instructor for display 10.



Using the illustration above, draw the symbols that represent each of the following units.

1. Internal view of a fixed resistor.
2. Push-pull type circuit breaker.
3. Ground symbol.
4. Internal view of a potentiometer.
5. Fuse.
6. Internal view of a rheostat.
7. View of a sensor.

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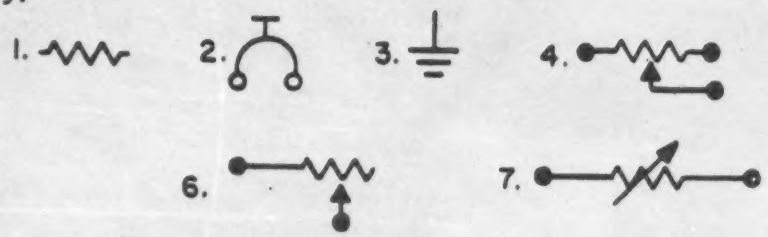
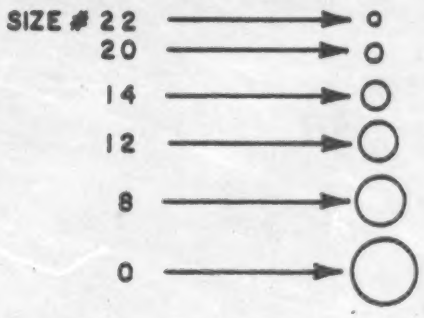
Answers to Frame 9:



Frame 10

Illustrated below is an example of how wires are sized. If a wire is to carry a large amount of current it must be a large wire. These are not drawn to scale but simply represent the difference in sizes and the manner in which they are numbered or "sized."

Note: See instructor for display 8.



It is impossible to cover every symbol that you will find on aircraft wiring diagrams. Each aircraft has a technical manual which is referred to as a wiring diagram handbook which contains the symbols that will be used on the aircraft's wiring diagrams. It is a good idea to review these symbols so that reading the diagram will have meaning to you.

Place the letter T beside each of the following statements that are true.

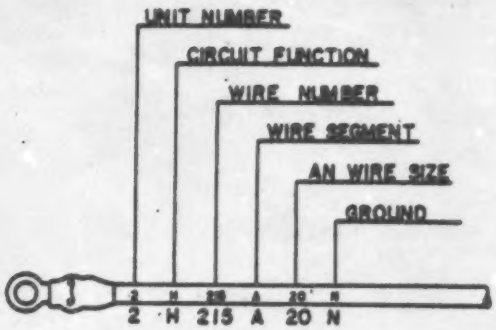
_____1. The symbols used on an aircraft wiring diagram can be found in the wiring diagram handbook for that particular aircraft.

_____2. A wiring diagram will have meaning if you can interpret the symbols that are used.

Answers to Frame 11: 1. G 2. D 3. H 4. A 5. F 6. J 7. E 8. I 9. C 10. K 11. B

Frame 12

To aid installation and troubleshooting of wiring, each wire, except shielded wire or high-temperature wire, is identified by a letter-number combination, as shown in the illustration below, stamped at about 15 inch intervals along the entire length of the wire. The wire is also identified within three inches of a junction or terminal point. The wire identification code contains a unit number (when applicable), a circuit function letter, a wire number, a wire segment letter, a wire size number, and in some cases, a phase letter and a ground, kit, or test letter. In any case, it is best to check each technical order wiring diagram you use to see exactly how the wire is coded on the aircraft you are maintaining.



Place the letter T beside each of the following statements that are true.

_____1. A wire number consisting of a combination of letters and numbers is used to identify wires.

_____2. The wire number should be stamped at about 15 inch intervals along the entire length of the wire.

_____3. The wire number is also stamped on shielded or high-temperature wire.

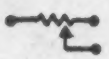
_____4. The wire number will aid in the installation and troubleshooting of a wire.

Answers to Frame 10: 1. T 2. T

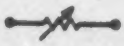
Frame 11

Place the letter of the symbol from column B beside the correct name for that symbol in column A.

	Column A	Column B
____1.	Actuator motor	
____2.	Push pull circuit breaker and bus bar	
____3.	Single pole double throw relay	
____4.	Potentiometer (variable resistor)	
____5.	Fuse and fuse holder	
____6.	Crossed path conductors	
____7.	Ground	
____8.	Rotary switch	
____9.	Variable resistor (sensor)	
____10.	Single pole double throw switch	
____11.	Fixed resistor	

A 

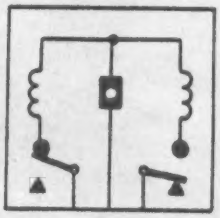
B

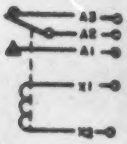
C 

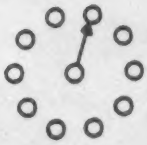
D

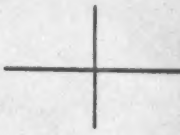
E

F

G 

H 

I 

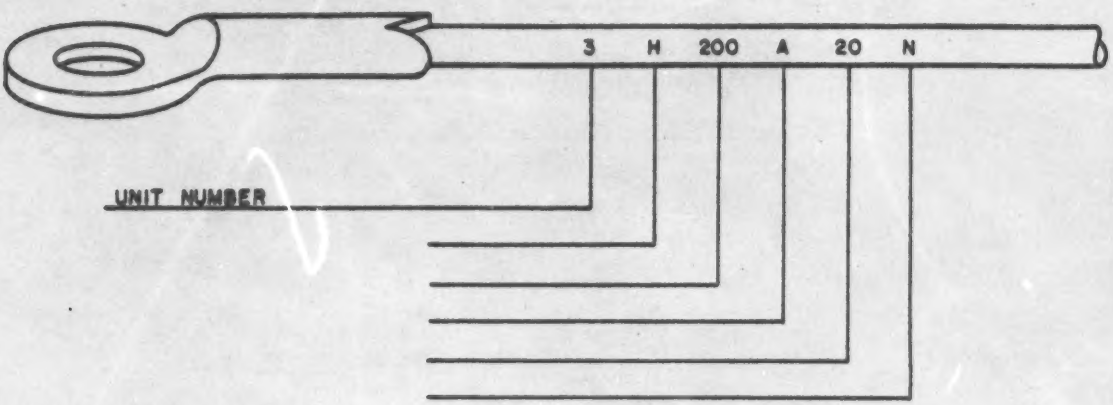
J 

K

Answers to Frame 12: 1. T 2. T 3. F 4. T

Frame 13

The unit number, shown in the illustration below, is used to designate the circuit where there are two or more identical circuits on the aircraft. An example of this would be the engine anti-icing circuits found on a multi-engine aircraft such as the C-130. The engine anti-icing systems are identical in construction so to tell the difference in the circuits, the circuit for engine one would have the unit number 1, the circuit for engine two would have the unit number 2 and so on.



Place the letter T beside each of the following statements that are true.

_____1. The unit number is used to identify the circuit when there are two or more identical circuits on the aircraft.

_____2. The unit number 1 will be found stamped on the wires of the anti-icing system in engine number 3.

_____3. Identical aircraft electrical circuits carry the same unit number.

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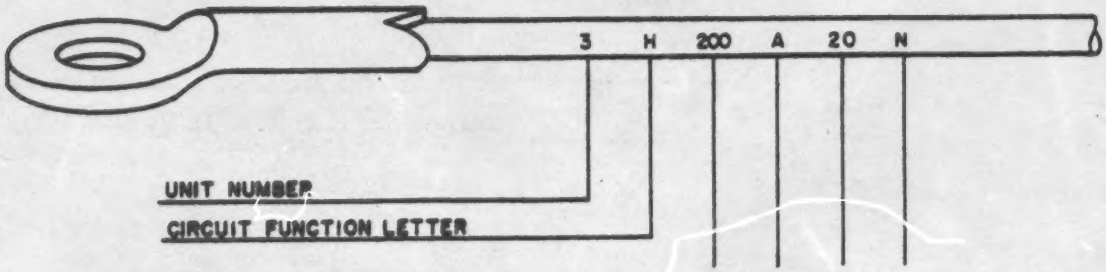
Answers to Frame 13: 1. T 2. F 3. F

Frame 14

The circuit function letter, shown below, is used to identify the major system the wire is in. The circuit function letter (H) is used to identify a circuit in the major system of heating, ventilation, and de-icing



Complete the following statements.

1. In the wire number M8D20 the circuit function letter or major system is indicated by the letter _____.

2. The circuit function letter in wire number H35B20 is indicated by the letter _____.

3. In the wire number 2Q384C22 the unit number is the number _____.

4. The major system in wire number H188B18N is identified by the letter _____.

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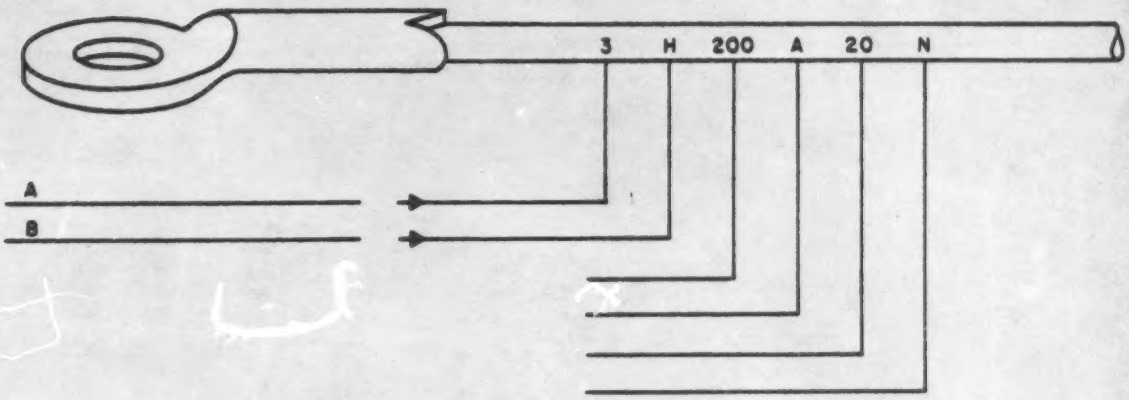
Answers to Frame 14: 1. M 2. H 3. 2 4. H

Frame 15

In the blank spaces (A and B) below write the identifying names for the first number and letter of the wire number.



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Answers to Frame 15: A. Unit number B. Major Systems or Circuit Function Letter

Frame 16

The following chart shows the circuits or systems identified by each circuit function letter and special circuit function letter. A chart similar to this will be found in the technical manual of electrical systems covering the aircraft you are working on.

CIRCUIT FUNCTION CODE LETTER	GENERAL DESCRIPTION OF CIRCUITS
A	Armament
B	Photographic
C	Control surfaces
D	Instrument (other than flight or engine)
E	Engine instrument
F	Flight instrument
G	Landing gear
H	Heating, ventilating, and de-icing
J	Ignition
K	Engine control
L	Lighting
M	Miscellaneous
P	D-C power
Q	Fuel and oil
R	Radio (navigation and communication)
S	Radar
T	Special electronic circuits
V	D-C power and d-c control cables for a-c system
W	Warning and emergency (other than those listed under specific functions)
X	A-C power
AL	Alumel (thermocouple coding)
CR	Chromel (thermocouple coding)

Code letters R, S, T, and X indicate functions to which additional coding must be added to identify specific functions. This identification is accomplished by adding a second letter as indicated in the following:

RADIO (NAVIGATION AND COMMUNICATION).

CIRCUIT FUNCTION CODE LETTER	GENERAL DESCRIPTION OF CIRCUITS
RA	Instrument landing
RC	Command
RF	VHF liaison
RH	Homing
RL	Liaison
RM	Market beacon
RN	Navigation
RS	SHF command
RU	UHF command
RV	VHF command
RX	Recorder
RZ	Interphone and headphone

RADAR.

SA	Altimeter
SG	Fire control system
SN	Navigation
SS	Search
SX	Recognition (IFF)

SPECIAL ELECTRONIC.

TA	Adapters
TB	Radar control
TC	Radio control
TF	Repeat back
TG	Glide homing
TM	Chaff dispenser
TN	Navigation
TQ	Transmitters and receivers
TR	Receivers
TS	Antisubmarine (ASW)
TT	Transmitters
TX	Television transmitters
TY	Television receivers
TZ	Bombing devices

A-C POWER.

XA	Phase A
XB	Phase B
XC	Phase C
XN	Neutral or ground
XP	Inverter or alternator (d-c power or control)
XV	Inverter or alternator (single-phase a-c power or control)

Using the chart above, place the circuit function code letter in the blank space beside the general description of the circuit.

_____1. Miscellaneous

_____2. Warning and emergency

_____3. Heating, ventilating and de-icing

_____4. Phase A of AC power

_____5. Phase C of AC power

_____6. AC power neutral or ground

_____7. DC power

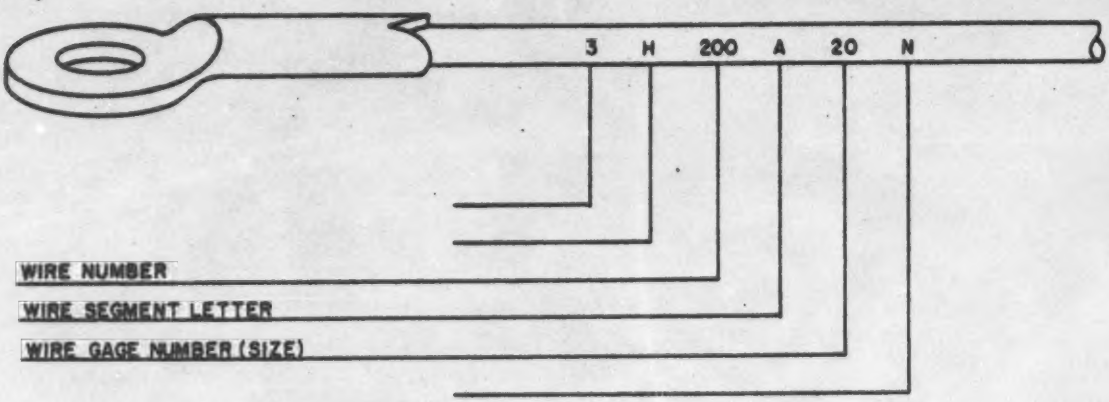
_____8. AC power

Answers to Frame 16: 1. M 2. W 3. H 4. XA

5. XC 6. XN 7. P 8. X

Frame 17

The illustration below shows the next 3 portions of the wire number. The wire number is used to tell the difference between wires in a particular circuit. A different number is used for wires not having the same junction or terminal. The wire segment letter is used to tell the difference between wire sections in a particular circuit. The wire segment code letter changes each time the wire is broken at a plug or terminal strip. The wire gage (wire size) number identifies the AN or AL size of the wire.



Place the letter T beside each of the following statements that are true.

_____1. The wire number will remain the same for a complete wire run that interconnects equipment.

_____2. The wire number is used to tell the difference between wires in a particular circuit.

_____3. The wire segment letter remains the same for a complete wire run.

_____4. If pressure bulkhead connector plugs are used on a complete wire run, the wire number will remain the same, but the wire segment letter will change each time a connector plug breaks the wire.

_____5. The size of wire used in the circuit is identified by the wire gage number.

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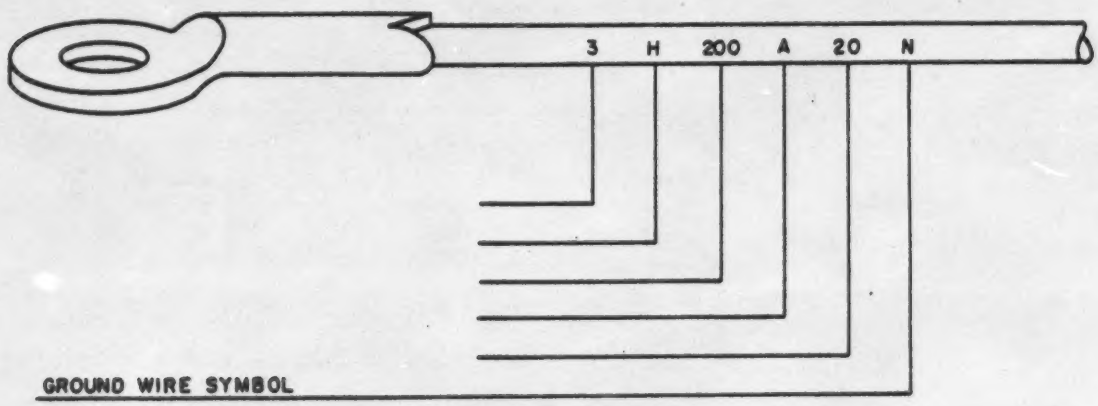
Answers to Frame 17: 1. T 2. T 3. F 4. T 5. T

Frame 18

The ground letter is used at the end of the wire identification code, as shown in the illustration below, to identify any wire that completes the circuits to ground. The ground letter (N) can be replaced with a kit letter (M) or a test letter (T). The kit letter (M) is used when the wire segment or circuit has been modified by a modification kit. The test letter (T) is used when the wire segment or circuit has been modified or added for testing purposes.



Place the letter T alongside each of the following statements that are true.

_____1. The ground wire symbol (N) is used at the end of the wire identification code to indicate a wire connected to ground.

_____2. If a wire segment or circuit has been modified or added for testing purposes, the letter T is added at the end of the wire identification code.

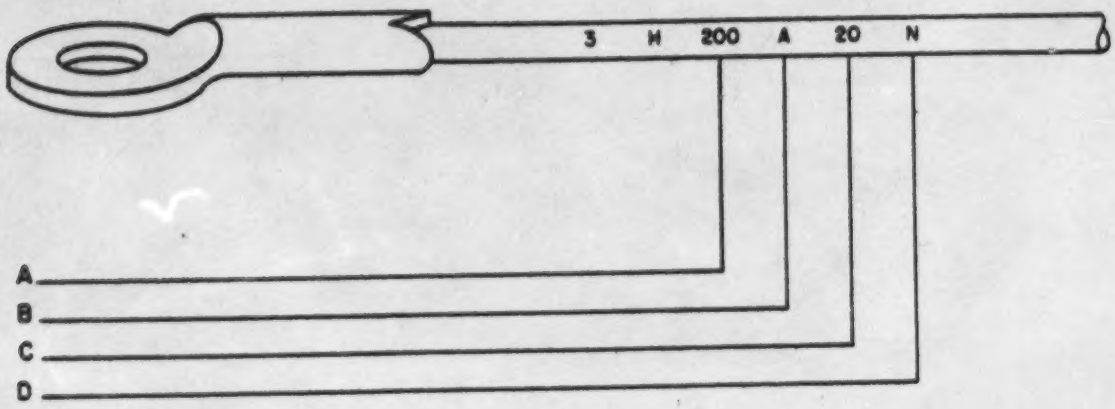
_____3. The kit letter will be added to the end of the wire identification code when the wire segment or circuit has been modified by a modification kit.

_____4. The ground wire letter, kit letter, and test letter will be found at the beginning of each wire identification code.

Answers to Frame 18: 1. T 2. T 3. T 4. F

Frame 19

In the blank spaces provided in the illustration below write in the identifying names for the last four numbers and letters of the wire identification code.



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Answers to Frame 19: A. wire number B. wire segment letter

C. Wire gage number (size) D. Ground wire symbol

Frame 20

Match the letters from the illustration below to the identifying names for each letter and number in the wire identification code.

_____ 1. Wire number

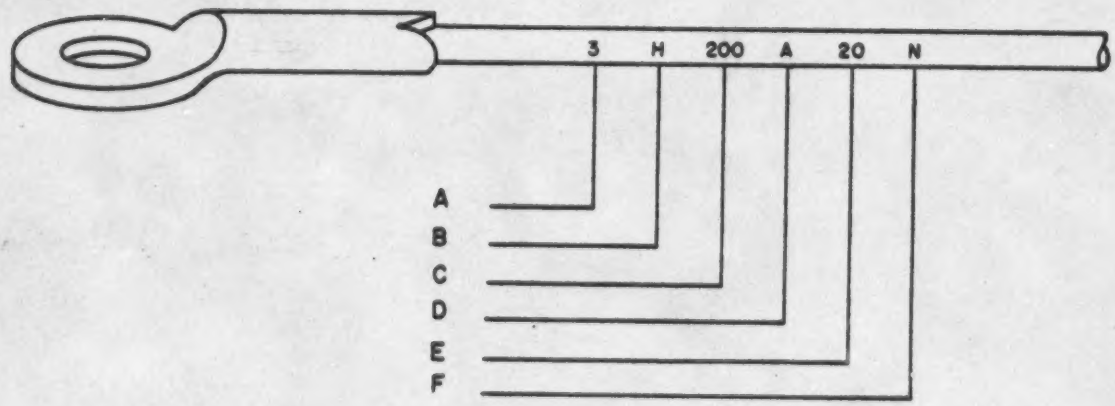
_____ 2. Ground wire symbol

_____ 3. Unit number

_____ 4. Wire size

_____ 5. Circuit function

_____ 6. Wire segment



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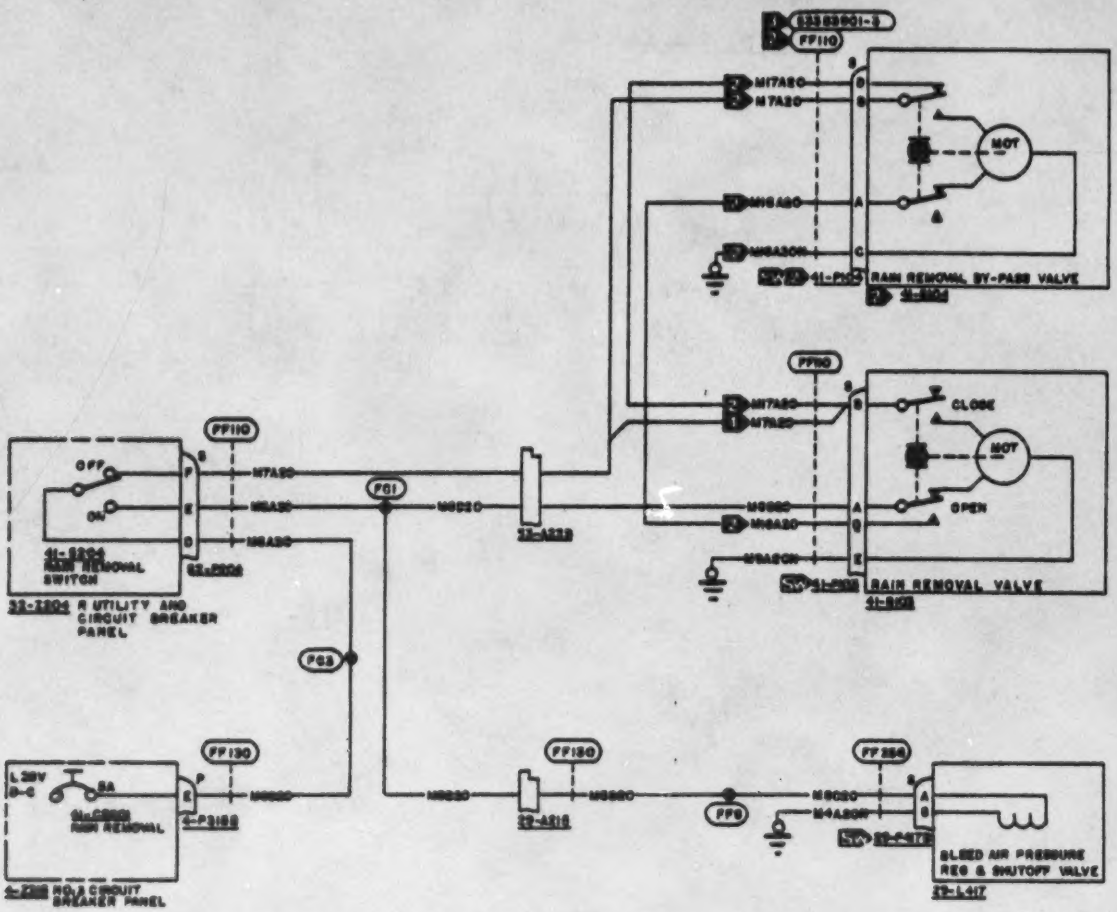
Answers to Frame 20: 1. C 2. F 3. 4 4. E 5. B 6. D

Frame 21

Use the wiring diagram shown below to complete the following statements.



1. The wire that connects to pin C of the rain removal valve is numbered _____.

2. The symbol for the rain removal circuit breaker indicates it is a _____ type. (push pull, switch)

3. The splice symbol between wires M8A20, M8B20, and M8D20 indicates the splice is _____ (temporary, permanent).

4. The symbol for the rain removal switch identifies it as a _____ (single pole-single throw, a single pole-double throw).

5. In the wire number M9A20N:

   a. The 9 indicates the _____. (Size of wire, wire number)

   b. The N indicates the wire is a _____ (power or ground wire).

   c. The M indicates the _____ (circuit function, major

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Answers to Frame 21: 1. M16A20 2. Push-pull 3. permanent

4. single pole double throw 5a. a wire number 5b. ground

5c. circuit function

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PROGRAMMED TEXT
3ABR42331-PT- 111

Technical Training

Aircraft Environmental Systems Mechanic

CONTROL AND PROTECTIVE DEVICES

17 August 1977

3350 TECHNICAL TRAINING WING
3370 Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE
DO NOT USE ON THE JOB

ATC FORM 214 (JAN 76) OBSOLETES ATC FORMS 214, MAY 69, 522, NOV 63 AND 523, MAY 71. STANDARD COVERSHEET

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FOREWORD

This programmed text was prepared for use in the 3ABR42331 instructional system. The material contained herein has been validated using 30 students enrolled in the 3ABR42331 course. Eighty percent of the students taking this text surpassed the criterion called for in the approved lesson objective. The average student required 2.1 hours to complete the text.

OBJECTIVES

1. Select the control and protective devices used in electrical circuits with a minimum accuracy of 80%.

2. Select the basic symbols and terms used in electrical circuits with a minimum of 80% accuracy.

INSTRUCTION

Read each frame carefully, beginning with the first frame. Answer the questions at the end of each frame according to the instructions provided in each frame. Check your answers by comparing your response with the correct answers which are found on top of the following page. If you made an error, determine the cause of your error, and correct it before going on to the next frame. When you complete this lesson, contact your instructor for further instructions. Do not mark in this text. Write your answers on the response sheet.

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OPR: 3370 TTG
DISTRIBUTION: X
3370 TTGTC - 600; TTVSR - 1

Frame 1

Control and protective devices are very important parts in an electrical circuit. Control devices are used to control the paths for the flow of current. Protective devices are used to protect units and wiring in the event the load is too large. These types of devices are used in your houses as well as in aircraft. These devices are identified by symbols in schematic diagrams since it would be difficult to draw in a picture of each device. It is very important that you learn all about them and associate these devices by name, symbol, and their purpose in a circuit. Let us see what you already know about control and protective devices.

DO NOT MARK IN THIS TEXT

Mark the correct answer for each of the following questions on the response sheet.

_____1. An example of a protective device is a

a. switch.
b. fuse.

_____2. A fuse is used for the same purpose as a

a. switch.
b. circuit breaker.

_____3. If a fuse is wrapped with tin foil, it will provide protection for the circuit.

a. True
b. False

_____4. Switches are used

a. to control circuits.
b. as protective devices.

_____5. Circuit breakers are used

a. to control circuits.
b. as protective devices.

Answers to Frame 1: b 1. b 2. b 3. a 4. b 5.

Frame 2

If you have answered all of the questions correctly in frame 1, this shows that you do know a little about control and protective services. But, let us take a more detailed look at these units. We will start with the control devices. Control devices are known as switches. Although there are hundreds of types of switches, all of them can be grouped in one of four types. The four types of switches are manual, mechanical, magnetic operating types and electronic devices. We will study the first three in this text. The fourth, an electronic device, will be studied later.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on the response sheet.

_____1. A magnetic switch is a circuit control device.

_____2. Fuses are used to control a circuit.

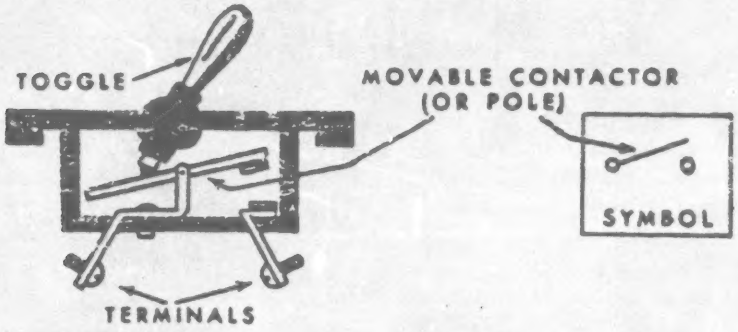
_____3. There are hundreds of classes of control devices.

_____4. Control devices are used to control paths for current to flow.

Answers to Frame 2: __T__ 1. _____2. _____3. __T__ 4.

Frame 3

Let us study the manual switches first. A sample of a SPST switch can be found in display board number nine in your classroom. The most common type of manual switch is known as the toggle switch. This switch has a toggle which you must operate manually to open or close the switch internal electrical path. When we say manually, it means you must physically move the toggle. Let us take a look at a simple toggle switch. If we learn the principles of this switch, they can be used for all toggle switches, shown here.



All toggle switches have poles. A pole is the movable contactor. Since the switch above has only one movable contactor, it is known as a single pole (SP) switch. When the toggle is moved to the other position, it pushes the pole down to make contact with the terminal on the right, completing the circuit to both terminals.

DO NOT MARK IN THIS TEXT

Mark the correct answer for each of the following questions on the response sheet.

_____1. When the toggle is moved to the ON position the poles which are internal contacts are

a. close.
b. open.

_____2. Poles are also known as

a. positions.
b. movable contactors

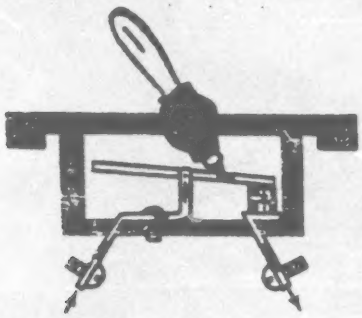
_____3. The switch above is shown in the

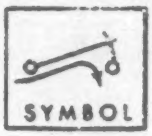
a. closed position.
b. open position.

Answers to Frame 3: a 1. b 2. b 3.

Frame 4

Switches also have movements called throws. This means the number of "ON" positions the switch has, which means the number of paths where current can flow. In the switch below there is only one ON position or one path for current to flow. Therefore, this is known as a single throw (ST) switch. Notice the symbol below on the right. This is the way we show, on a schematic diagram, that the switch is closed.





Notice that there is now a complete path for current flow through the switch. This path is shown by a series of arrows in the above switch.

DO NOT MARK IN THIS TEXT

Mark the following true statement with a "T" on the response sheet.

_____1. The switch above is known as a SPST toggle switch.

_____2. The number of throws a switch has is equal to the number of terminals on the bottom of the switch.

_____3. The switch above is shown in the CLOSED or ON position.

_____4. SPST stands for simple polarized switch terminals.

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Answers to Frame 4: __T__ 1. ____ 2. __T__ 3. ____ 4.

Frame 5

To make a complete identification of a toggle switch, there is one more thing you should know. That is the number of positions it has. The switch shown in frames 3 and 4 has only two positions; they are, one "ON" position, and the other is the "OFF" position.

DO NOT MARK IN THIS TEXT

Choose one of the answers provided and write its letter on the response sheet.

1. The switch you have learned about so far can be completely identified by calling it a

   a. SPST 2-position knife switch.
   b. SPDT 2-position toggle switch.
   c. SPST 2-position toggle switch.
   d. SPST 3-position toggle switch.

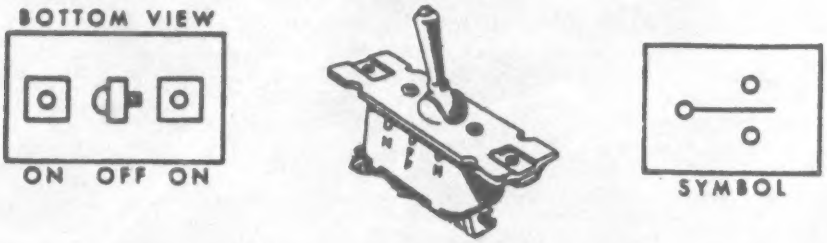
Use frame 35 to answer the following question on the response sheet. The blank may require more than one number.

2. SPST toggle switches are identified by what number(s) in frame 35?

Answers to Frame 5: 1. c 2. 1,3,6

Frame 6

Now let us look at another manual switch. Apply the same things you have already learned, and see if you can figure out how it works in a circuit. Be sure and look at the symbol which represents this switch. See display #9 in your classroom.



DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on the response sheet.

_____1. The above switch has two positions.

_____2. The above switch has two throws.

_____3. The above switch is a toggle switch.

_____4. The above switch could be classified as a double pole switch.

_____5. The above switch could be used to complete two circuits, but not at the same time.

Choose one of the answers provided and write its letter on the response sheet.

6. The switch above could be identified completely by saying it is a

   a. DPDT, 3-position toggle switch.
   b. SPDT, 3-position toggle switch.
   c. DPDT, 2-position toggle switch.
   d. SPST, 3-position toggle switch.

Use frame 35 to answer the following question on the response sheet. The blank may require more than one number.

7. SPDT 3-position toggle switches are identified by what number(s) in frame 35?

Answers to Frame 6: ____1. T 2. T 3. ____4. T 5.
6. b 7. 9 & 11

Frame 7

There are other switches which act almost like a normal SPST, SPDT, etc., but are called momentary throws. This means that one or more of the throws is spring loaded to the OFF position.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on the response sheet.

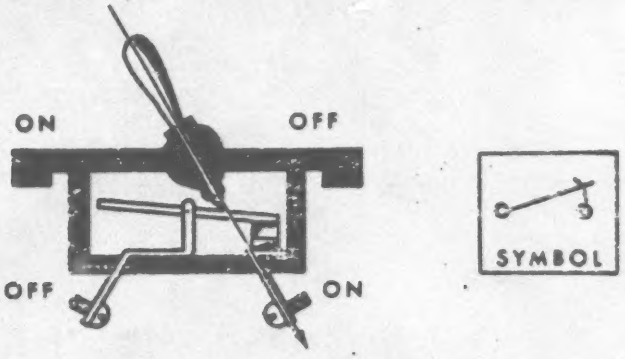
____1. When the switch is placed to one of the ON positions and released, it springs back to the OFF position.

The symbols below indicate that there are momentary thows in only the direction of the triangle.

Answers to Frame 7: T 1.

Frame 8

Since you are not able to look inside a switch to figure out how many poles it has in it, there is a way you can find out. Place a toggle switch in any of the ON positions. Now draw an arrow through the center of the toggle, and count the number of terminals it points to. Look at the illustration shown.



Since the arrow points to only one terminal, this is a SP switch. If there were two terminals in a row, it would be a DP switch, etc. Sometimes the switch positions are marked on the switch case. The marks show the position of the toggle. We can tell which terminal will match one or the other of either of the positions by using the same arrow as above. Look and see that the switch is in the ON position. The arrow points to the ON terminal.

DO NOT MARK IN THIS TEXT

Mark the correct answer for each of the following questions on the response sheet.

____1. The ON terminal at the bottom of the switch above is on the

a. opposite side of the ON position of the toggle.
b. same side of the ON position of the toggle.

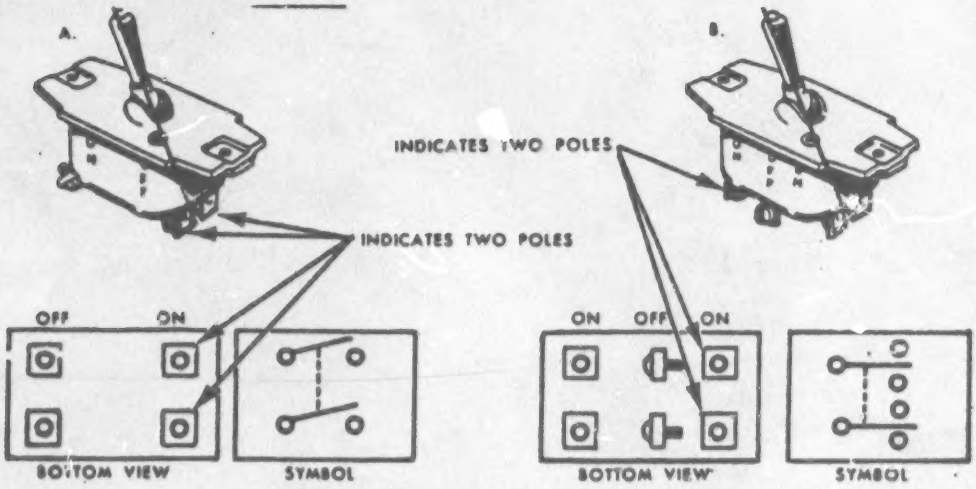
____2. If the switch is in the ON position, and it points to a row of three terminals, we have a

a. double pole (DP) switch.
b. triple pole (TP) switch.

Answers to Frame 8: a 1. b 2.

Frame 9

Now let us look at some toggle switches and see if you can identify them.



The dashed lines between the poles on the symbols mean that the two poles are mechanically linked together. If you move the toggle to the ON position, both poles go to the ON position. Notice the ON and OFF positions are marked on the switch case, and arrow through the center of the toggle points to the terminals which match up with the toggle ON position. Study the DPDT in display #9 in your classroom.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on the response sheet.

_____1. The switch in figure A is a DPST, 2-position toggle switch.

_____2. The toggle in figure A points to two poles.

_____3. The switch in figure A is a 3-position switch.

_____4. The switch in figure B is a DPDT, 2-position toggle switch.

_____5. The switch in figure B is a 4-pole toggle switch since the total number of terminals in ON positions is four.

_____6. The switch in figure B is a 3-position switch.

Frame 9 (continued)

Use frame 35 to answer the following question on the response sheet. The blank may require more than one number.

_____7. DPST toggle switches are identified by what number(s) in frame 35?

_____8. DPDT toggle switches are identified by what number(s) in frame 35?

Answers to Frame 9: T 1. T 2. ____3. ____4. ____5.
T 6. 2,10 7. 12 8.

Frame 10

We have talked about symbols a number of times in the past frames. Let us see what you have learned about them. All of the items listed below are toggle switches.

DO NOT MARK IN THIS TEXT

Match the switches to their symbols. Write the letter representing the symbol in the proper blank on the response sheet.

____1. SPDT, 2-position

____2. DPST, 2-position.

____3. SPST, 2-position.

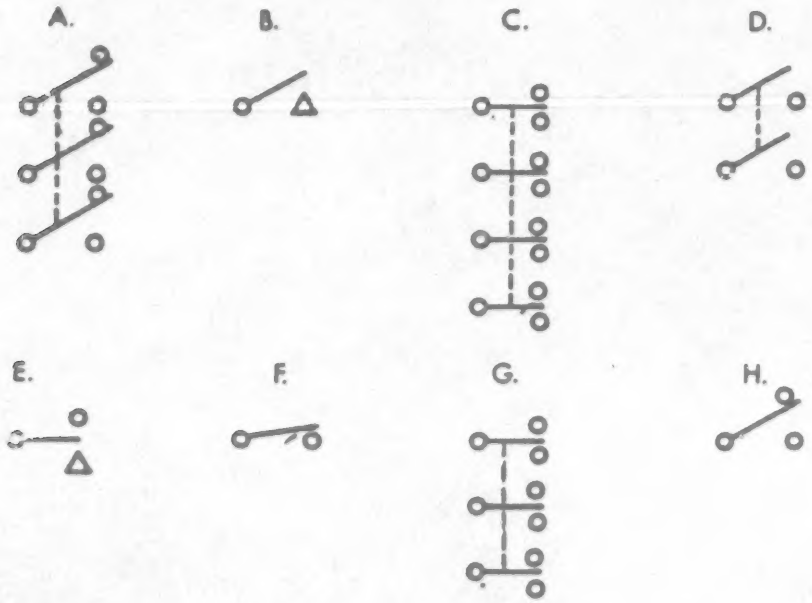
____4. SPST, 2-position, spring loaded to OFF.

____5. SPDT, 3-position, 1 position spring loaded to OFF.

____6. TPDT, 2-position.

____7. TPDT, 3-position.

____8. 4PDT, 3-position.



Answers to Frame 10: h 1. d 2. f 3. b 4. e 5.

a 6. g 7. c 8.

Frame 11

Using the list of switches below, locate the switches in frame 35 and enter the switch number in the blanks provided on the response sheet. Again we are talking about toggle switches only. It is possible that more than one number can go in a blank.

DO NOT MARK IN THIS TEXT

_____a. SPDT, 2-position.

_____b. 4PDT, 3-position, 1 position spring loaded to OFF.

_____c. DPST, 2-position.

_____d. SPST, 2-position, spring loaded to OFF.

_____e. 4PDT, 3-position.

_____f. DPDT, 3-position.

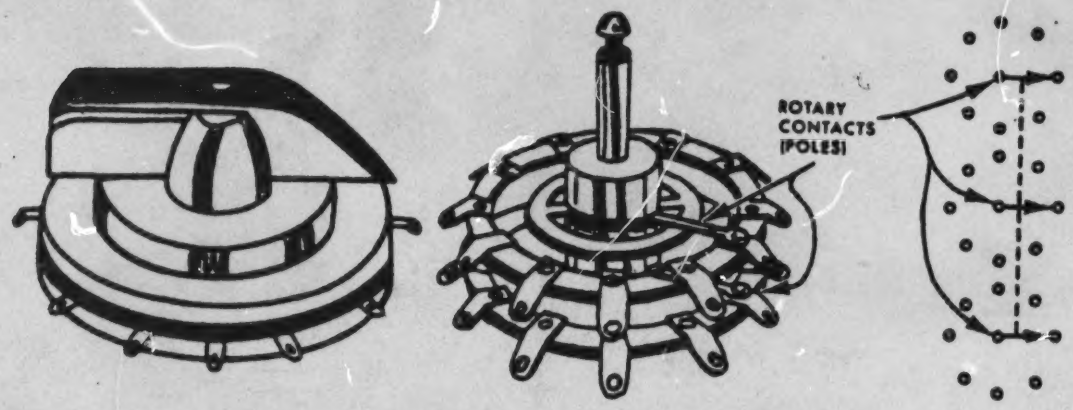
_____g. SPDT, 3-position, 1 position spring loaded to OFF.

480

Answers to Frame 11: 19 a. 17 b. 2,10 c. 3 d. 18 e.
12 f. 11 g.

Frame 12

Another type of manual switch is the rotary selector switch as shown below. When the knob of the switch is turned, the switch opens one circuit and closes another. Sometimes there are a number of wafers stacked, one on top of the other. When the knob is in any one position, it will complete a circuit in that position for each wafer. This type switch is used as the function switch on multimeters. Study the rotary switch stack type in your classroom display board #9.



DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on the response sheet.

_____1. The dashed line in the schematic symbol, figure C, means that all the poles are mechanically linked together.

_____2. The schematic symbol, figure C, shows that the switch is a triple-pole (TP) 8-position rotary selector switch.

_____3. The drawings above are all of the same switch.

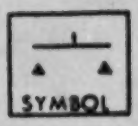
Use frame 35 to answer the following questions on the response sheet. The blank may require more than one number.

_____4. Rotary selector switches are identified by what number(s) in frame 35?

Answers to Frame 12: T 1. T 2. ____3. T 4.

Frame 13

One more type of manual switch used on the aircraft is shown below. It is known as a push button switch. This type is used in your home to ring the door bell. On the aircraft it can be used as a microphone button. When the pilot wants to talk over the radio he simply pushes the microphone button.



DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on the response sheet.

____1. To complete the circuit, the button is pressed.

____2. When the button is released, the circuit is broken.

____3. This would be a good switch to use in a lighting circuit.

____4. The triangles in the symbol represent momentary contacts which means the switch is spring loaded to OFF.

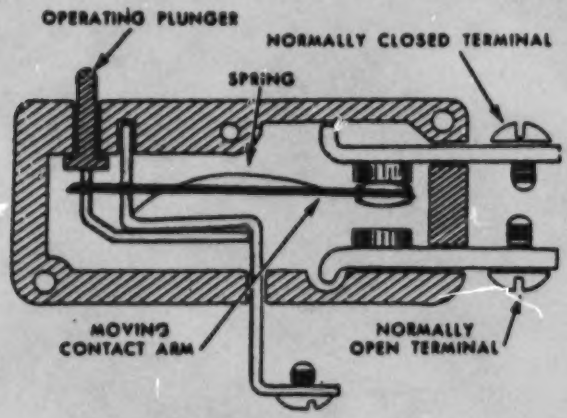
Use frame 25 to answer the following question on the response sheet. The blank may require more than one number.

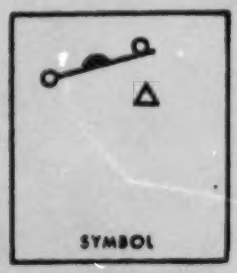
____5. Push button switches are identified by what number(s) in frame 35?

Answers to Frame 13: T 1. T 2. ___3. T 4. 15 5.

Frame 14

Mechanical switches will be the next group of switches that we will study. The word mechanical means that they are operated by some mechanical device. These switches are shown as normally open (NO) or normally closed (NC) depending on the position to which they are spring loaded. They will always be spring loaded to one of these positions, and will have no center OFF position. This kind of switch is called a microswitch or limit switch.





SPDT MICROSWITCH

The operating plunger in some way will always be hooked to some kind of spring as shown in the drawing above. When some kind of mechanical thing pushes the plunger down, the switch will change positions. The switch can be wired to either the NO or NC. Each of the positions can complete a circuit, or only one set of contacts may be used. It all depends on where the switch is used.

DO NOT MARK IN THIS TEXT

Mark the correct answer for each of the following questions on the response sheet.

_____1. The switch shown above is a

a. NC microswitch.
b. NO microswitch.

_____2. The switch shown above is a

a. two-position switch.
b. three-position switch.

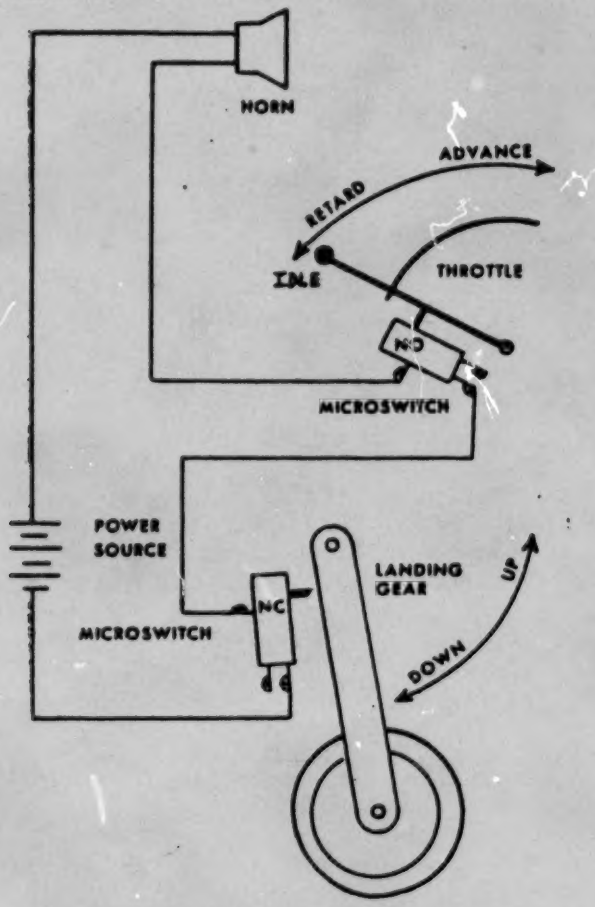
_____3. In the above switch the moving contact arm could be called the

a. pole.
b. position.

Answers to Frame 14: a 1. a 2. a 3.

Frame 15

Let us see how two switches like the one in frame 14 can be used in a circuit. One of the switches is NO and the other is NC. In the schematic, the throttle microswitch is NO and the gear switch is NC. This means if the throttle were pulled back to idle, the mechanical hook up would press the plunger in the switch and close the circuit. If the gear is down and locked, the plunger would be pressed to open the circuit. With the condition shown the warning horn would sound, warning the pilot that his gear is not down and locked. Normally, the throttle is only retarded when the pilot is attempting to land.



Mark the following true statements with a "T" on the response sheet.

_____1. If the throttle is retarded and the gear is down and locked, the warning horn will sound.

_____2. When the gear comes down, the gear switch will OPEN.

Frame 15 (Continued)

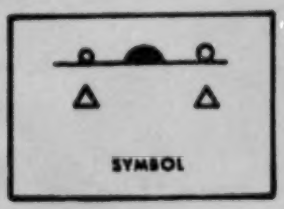
_____3. When the throttle is retarded, the throttle microswitch will OPEN.

_____4. The purpose of the above circuit is to warn the pilot if his gear is not down when he is attempting to land.

Answers to Frame 15: ____1. __T__2. ____3. __T__4.

Frame 16

The symbols for microswitches can be drawn several ways, but they are all easy to identify by the little hump drawn over the pole. Another symbol for a microswitch is drawn below.



DO NOT MARK IN THIS TEXT

Use frame 35 to answer the following question on the response sheet. The blank may require more than one number.

____1. Microswitches are identified by what number(s) in frame 35?

Mark the following true statements with a "T" on the response sheet.

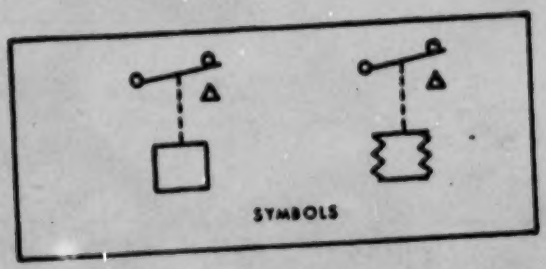
____2. Microswitches can be identified as SPDT, 2-position, etc.

____3. The switch identified by the symbol above would be a SPDT, 2-position microswitch.

Answers to Frame 16: 4, 14 1. T 2. T 3.

Frame 17

Mechanical switches can also be operated by other means. In hydraulic or pneumatic systems, we need something to tell us when the pressure is too high or too low. Because of this, we have a need for pressure switches. The symbol for a pressure switch can be drawn two ways. Examples are shown below.



Both of the symbols above represent pressure switches which would move from normally CLOSED to momentary ON position when the pressure builds up to a given amount. REMEMBER: Whenever you see dashed lines under a switch, the lines represent only mechanical linkage (connection), not circuit (electrical) connections.

DO NOT MARK IN THIS TEXT

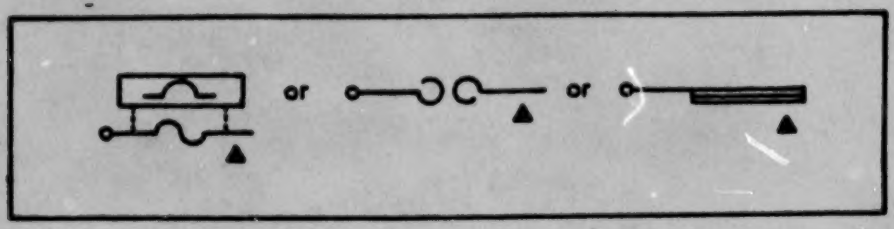
Use frame 35 to answer the following question on the response sheet. The blank may require more than one number.

_____1. Pressure switches are identified by what number(s) in frame 35?

Answer to Frame 17: 16 1.

Frame 18

Another type of mechanical switch is operated by heat. It is often used when time delays are needed in the circuit. It takes a little time for the switch to warm up and then close. Several symbols for the heat or thermal switch are shown below.



When the element (not shown in the symbols) is heated, the metals expand to touch the contact, completing the circuit. Other uses for thermal switches are as warning switches and temperature sensing devices.

DO NOT MARK IN THIS TEXT

Use frame 35 to answer the following question on the response sheet. The blank may require more than one number.

_____1. Thermal switches are identified by what number(s) in frame 35?

Answer to Frame 18: 5 1.

Frame 19

You have now covered most of the control devices in frame 35. Let us see what you have learned.

DO NOT MARK IN THIS TEXT

Match the switches to their symbols. Write the letter representing the symbol in the proper blank on the response sheet.

_____1. SPST pressure switch.

_____2. SP rotary selector switch.

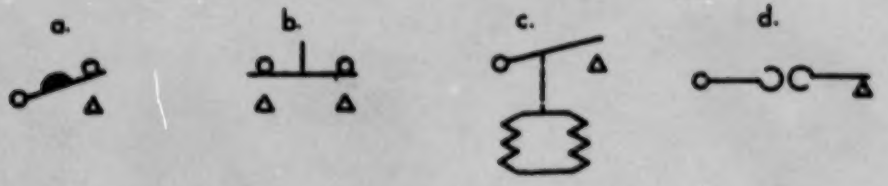
_____3. SPDT microswitch.

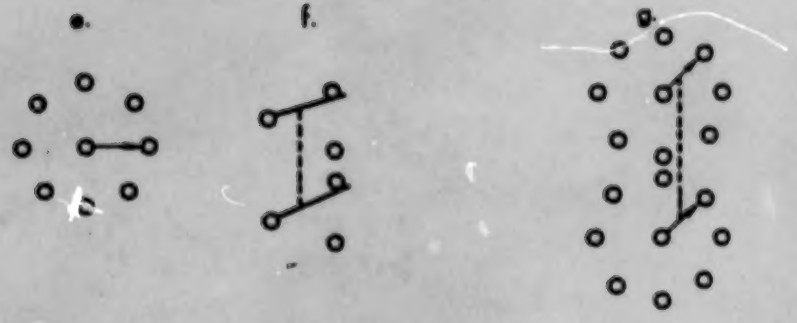
_____4. DPDT toggle switch.

_____5. SPDT push button switch.

_____6. DP rotary selector switch.

_____7. Thermal switch.

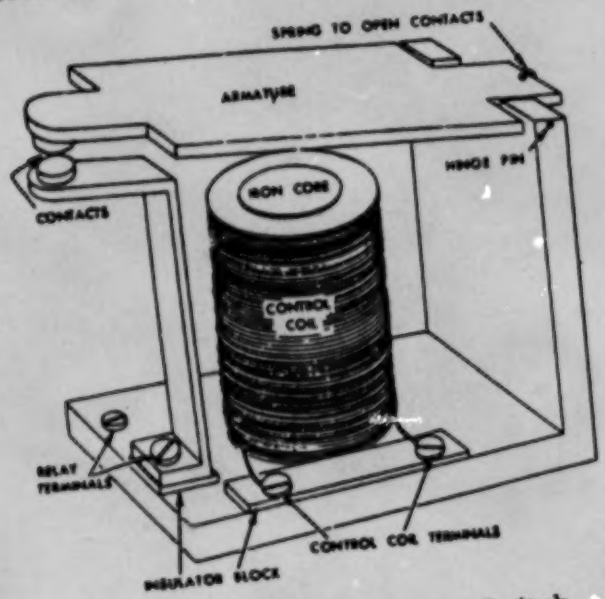


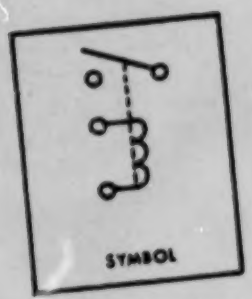


Answers to Frame 19: c 1. e 2. a 3. f 4. b 5. g 6. d 7.

Frame 20

This brings us to the third class of switches; the magnetic type. These switches are better known as relays and can be placed into two different types, fixed core and movable core. See display #9 in your classroom for relay displays.





The Relay is a Switch Operated by an Electromagnet.

The relay shown on this page has a fixed core. When current passes through the coil surrounding the core, it produces an electromagnetic field which attracts the iron armature and pulls it down against spring tension. This closes the contacts to complete the circuit. When there is no current flow in the coil, the spring tension opens the contacts.

DO NOT MARK IN THIS TEXT

Mark the correct answer for each of the following questions on the response sheet.

____1. The relay shown is a

a. DPST relay.
b. SPST relay.

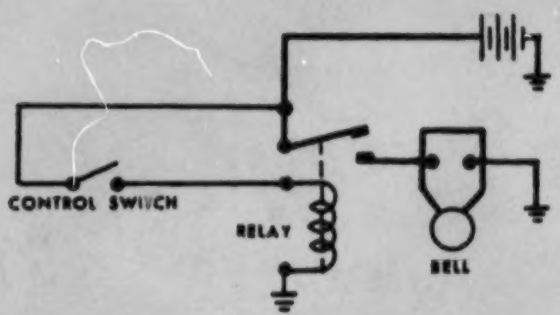
____2. A relay is actually a

a. switching device.
b. safety device.

Answers to Frame 20: b 1. a 2.

Frame 21

Relays are used to open or close circuits by remote control. Note that there are two distinct circuits. In the diagram below, both circuits use the same battery power source. The control circuit consists of the switch and the relay coil. The controlled circuit consists of the relay contacts and the bell which are in the circuit with the heavy dark lines.



The relay can be placed in the circuit close to the unit it controls. This eliminates a great amount of heavy wiring, thereby reducing aircraft weight. The relay is then controlled by smaller wires which can be operated from any place inside the aircraft.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on the response sheet.

____1. The circuit which causes the relay to operate could be called the control circuit.

____2. The relay contacts above are in the control circuit.

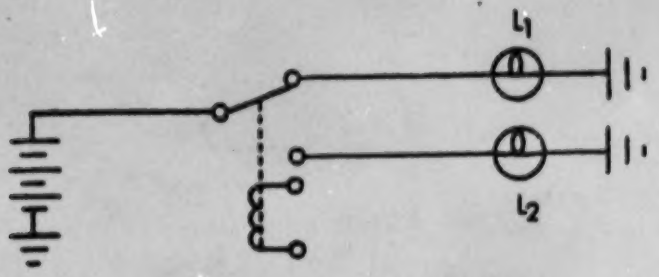
____3. The schematic above shows the relay coil mechanically linked to the relay armature.

____4. The bell circuit could be called the load circuit.

Answers to Frame 21: T 1. ____2. T 3. T 4.

Frame 22

So far we have avoided saying that a relay is either open or closed. The reason for this is explained in the following sentences. Let us take a look at another symbol for a relay wired in a simple circuit.



You can see that the relay above completes a circuit in either position. So, which position would be the CLOSED position? The answer is, both positions are CLOSED. Therefore it is far better to speak of a relay as being either energized or deenergized. Energized means that current is flowing through the coil pulling the contacts toward the coil. Relays are always drawn deenergized unless otherwise stated.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on the response sheet.

____1. The relay shown is a SPST relay.

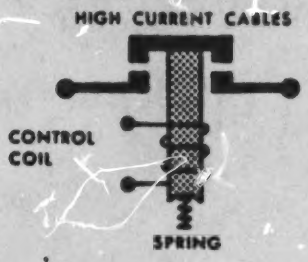
____2. When the relay is deenergized, the lamp #1 will glow.

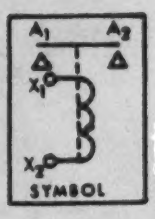
____3. Both lamps can operate at the same time.

Answers to Frame 22: ____1. __T__2. ____3.

Frame 23

There are probably just as many types of relays as there are toggle switches. Some relays require large amounts of current to flow through the contacts. You might say they are heavy duty relays. Their symbols are drawn as in the diagram on this page.





The coil hook ups are usually labeled X1 and X2, while the contacts are labeled A1 and A2, B1 and B2, etc. Notice that triangles are used to show mamomentary contacts the same as they do in toggle switches. These type of relays are often called solenoid relays and have movable cores. The soft iron core is hooked to the bar or bars at the top. When current flows through the coil, the electromagnet will tend to center the iron core into the hollow center of the coil.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on the response sheet.

____1. Solenoid relays are used as heavy duty relays.

____2. Solenoid relays have fixed cores.

____3. If you see the letters X_1 and X_2 on the terminals of a relay, you will know that these are the coil connections.

Use frame 35 to answer the following question on the response sheet. The blank may require more than one number.

____4. Relays are identified by what number(s) in frame 35?

Answers to Frame 23: T 1. ____2. T 3. 13 4.

Frame 24

DO NOT MARK IN THIS TEXT

Match the list of relays below to their symbols.

Write the letter corresponding to the proper symbol in the blanks provided on the response sheet.

_____1. SPDT fixed core relay.

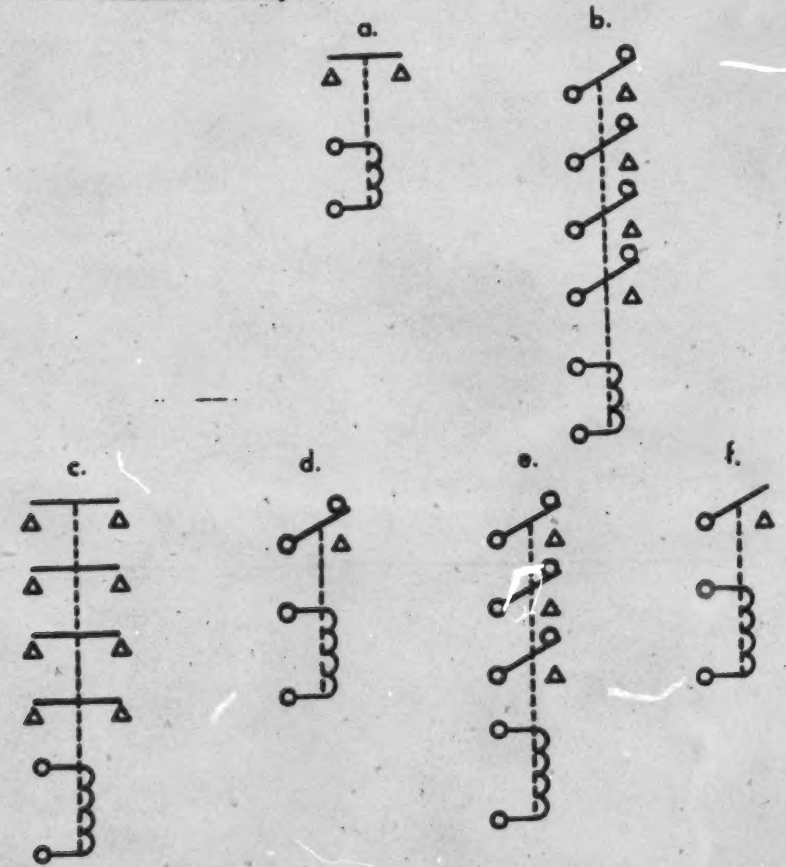
_____2. 4PDT fixed core relay.

_____3. TPDT fixed core relay.

_____4. SPST solenoid relay.

_____5. SPST fixed core relay.

_____6. 4PST solenoid relay.



Answers to Frame 24: d 1. b 2. e 3. a 4. f 5. c 6.

Frame 25

Use the list of relays below, and locate the relay in frame 36 of this text. Write the number of the relay in the blanks provided on the response sheet. A blank may require more than one number.

DO NOT MARK IN THIS TEXT

_____a. TPST relay.

_____b. 4PDT relay.

_____c. SPST relay.

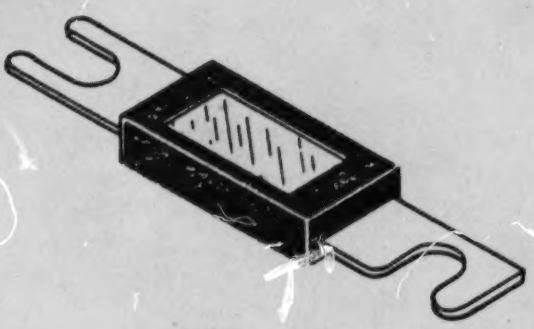
_____d. SPDT relay.

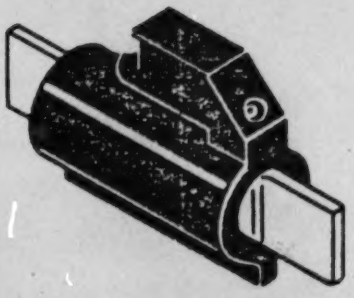
_____e. TPDT relay.

Answers to Frame 25: 4 a. 8 b. 1, 2, 5, 14 c. 7 d. 3, 6 e.

Frame 26

Now we are ready to discuss protective devices. The purpose of these devices is to protect electrical circuits from excessive overload or circuit damage. An overload means that too much current is flowing in the circuit. This condition can be caused by a short circuit, or trying to operate too many units on one circuit. Overloaded circuits cause the wire to overheat, and possibly burst into flames. Protective devices are known as fuses or circuit breakers. Let us talk about fuses first. Here are a few examples.





The fuses elements are made to melt at a much lower temperature than the wire in the circuit it is protecting. In case of an overload, the fuse element melts to open the circuit.

DO NOT MARK IN THIS TEXT

Mark the following true statements with a "T" on the response sheet.

_____1. A fuse rated at 5 amps would blow (burn out) if 6 amps were flowing in the circuit.

_____2. A protective device should be used in every circuit.

Use frame 36 to answer the following question on the response sheet. The blank may require more than one number.

_____3. Fuses are identified by what number(s) in frame 36?

Answers to Frame 26: T 1. T 2. 11, 12, 13 3.

Frame 27

Other types of fuses will allow a power overload for a short period of time before blowing. These type fuses are usually referred to as "slow blow" fuses. They are needed in electric motor circuits because motors require higher current for starting than they need for continuous running. If for some reason this higher current flow should go on past the starting stage, the fuse would blow, protecting the circuit. These fuses are perfectly safe since it takes a little time for the wires to heat up. If we put in exactly the right size fuse to protect the circuit wiring for a running motor, it would blow every time the motor started.

DO NOT MARK IN THIS TEXT

Mark the correct answer for each of the following questions on the response sheet.

_____1. High starting current would probably blow an ordinary

a. switch.
b. fuse.

_____2. "Slow blow" fuses will allow higher than rated current flow

a. temporarily.
b. indefinitely.

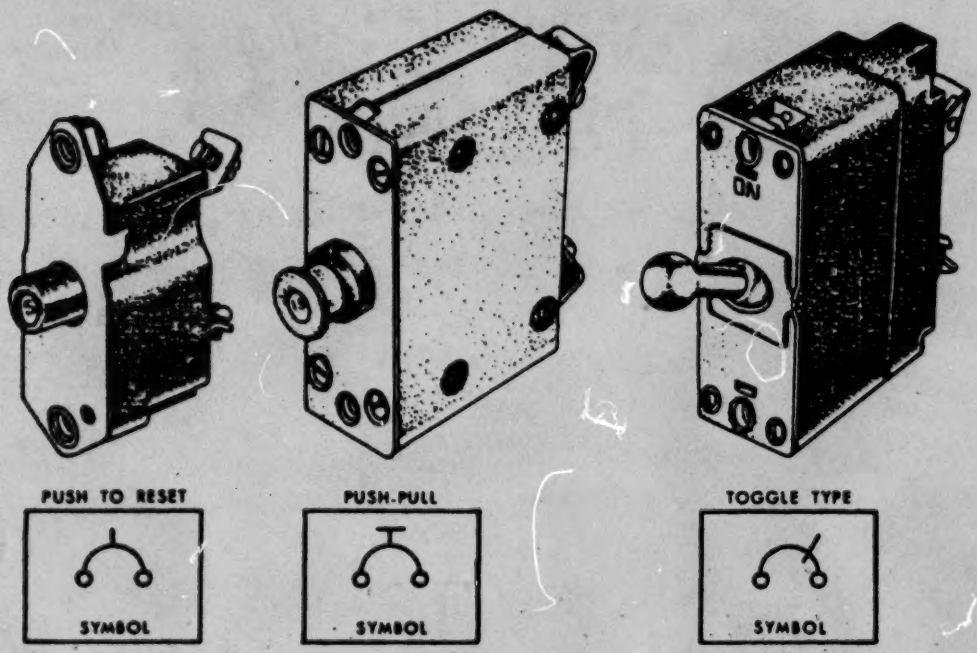
_____3. A blown 10 amp fuse was replaced in a 10 amp circuit. There would be a possibility of fire without the fuse ever blowing if it was replaced by a

a. 30 amp fuse.
b. 5 amp fuse.

Answers to Frame 27: b 1. a 2. a 3.

Frame 28

Another type of protective device is known as a circuit breaker. Three types of circuit breakers are shown below along with the symbol for each. Circuit breakers serve the same function as fuses, that is, to protect circuits in the event of an overload.



The push-pull and the toggle-type circuit breakers can be used to open a circuit manually, the same as you would do with a switch. All of these will work automatically to open the circuit in the event of an overload.

DO NOT MARK IN THIS TEXT

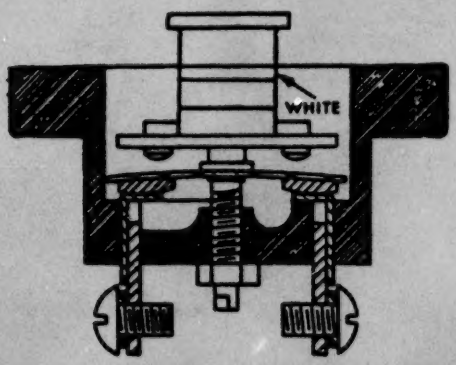
Use frame 36 to answer the following question on the response sheet. The blank may require more than one number.

_____1. Circuit breakers are identified by what number(s) in frame 36?

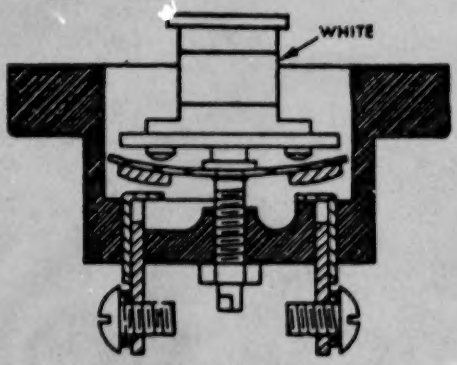
Answers to Frame 28: 9, 10 1.

Frame 29

Circuit breakers operate on the thermal effect of current. This means that wires and electrical components are heated by the current that flows through them. If too much current flows through a circuit breaker, the heat created by the current causes the circuit breaker to trip or "pop." You can tell at a glance when a push button or push-pull circuit breaker is tripped because of a white band around the button. When the button is pushed in, you cannot see the white band. When the cirjuit breaker is tripped, the white band is exposed. You can also tell when the toggle type circuit breaker is tripped, because it will be in the OFF position.



BREAKER CLOSED
ON NORMAL LOAD



CLICK! IT OPENS!
ON OVERLOAD

Mark the following true statements with a "T" on the response sheet.

_____1. The thermal effect which causes a circuit breaker to trip is caused by the applied voltage.

_____2. A circuit breaker is a device which prevents damage to circuit components.

_____3. You can tell when a circuit breaker is pushed in, because you can see the white band.

Answers to Frame 29: ____1. __T__2. ____3.

Frame 30

Fuses and circuit breakers should never be bypassed b: penny behind a fuse or wrapping a fuse with tinfoil. If a or a circuit breaker "pop," their is usually a good reason happen. If you bypass the protective device, a serious fi result. NEVER BYPASS A PROTECTIVE DEVICE. Neither should a protective device with one that has a larger rating than for in the circuit.

Mark the following true statements with a "T" on the sheet.

____1. A penny placed behind a fuse would cause the ci to be bypassed.

____2. Many fires are caused on aircraft because of th circuit protection.

____3. Bypassing the circuit protective device would having no protection at all.

Answers to Frame 30: __T__ 1. _____ 2. __T__ 3.

Frame 31

All control and protective devices are rated by current and voltage. Some devices have a data plate and others have the rating stamped on the side of the case. Always use devices with proper ratings in any circuit.

DO NOT MARK IN THIS TEXT

Mark the correct answer for each of the following questions on the response sheet.

_____1. Control and protective devices have two things in common. They are all rated in

a. current only.
b. voltage only.
c. current and voltage.

_____2. Ratings can usually be found some place on the control or protective device.

a. True
b. False

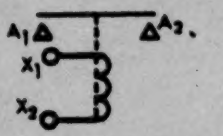
_____3. You should pay strict attention to the control and protective devices

a. manufacture title.
b. ratings.

Answers to Frame 31: c 1. a 2. b 3.

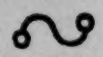
Frame 32

Now let's see what you have learned about control and protective devices. Match the terms on the right with the symbols on the left. Write the letter corresponding to the appropriate device in the blanks provided on the response sheet.



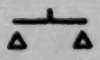
— — 1.

— — 2.

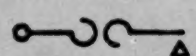


— — 3.

— — 4.

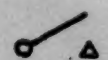


— — 5.



— — 6.

— — 7.



— — 8.

— — 9.

— — 10.

— — 11.

— — 12.

— — 13.

— — 14.

a. SPST "momentary on" switch

b. Push button switch

c. Circuit breaker (push-pull)

d. SPST relay (solenoid-type)

e. Thermal switch

f. SPDT switch (toggle)

g. Circuit breaker (push-to-reset)

h. Pressure switch

i. Rotary 8-position switch

j. Microswitch (limit switch)

k. SPST switch (toggle)

l. SPST relay (fixed-core type)

m. Circuit breaker (toggle-type)

n. Fuse

502

Answers to Frame 32: d 1. k 2. n 3. m 4. b 5.
e 6. j 7. a 8. g 9. i 10.
h 11. f 12. c 13. l 14.

Frame 33

Using the list of control and protective devices below, find these items to frames 35 and 36, and list their corresponding numbers in the blanks provided on the response sheet. You may have to use more than one number in a blank. It is NOT important that you list which frame the item is on, as long as you have the correct number in the proper blank.

_____a. SPST "momentary ON" switch (toggle)

_____b. Push-button switch

_____c. Circuit breaker (push-pull)

_____d. SPST relay (solenoid-type)

_____e. Thermal switch

_____f. SPDT switch (toggle)

_____g. DPDT switch (toggle)

_____h. Pressure switch

_____i. Rotary switch

_____j. Microswitch (limit switch)

_____k. SPST switch (toggle)

_____l. SPDT relay (fixed-core-type)

_____m. Circuit breaker (toggle-type)

_____n. Fuse

Answers to Frame 33: 3 a. 15 b. 9 c. 14 d. 5 e.
19, 11 f. 12 g. 16 h. 7 i.
4, 14 j. 1, 3, 6 k. 7 l. 10 m.
11, 12, 13 n.

Frame 34

Which of the following ratings are common to fuses, circuit breakers, and switches? Write the letter which identifies your answer on the response sheet.

a. Current, voltage and pressure.

b. Current, voltage, and blow characteristics.

c. Current, voltage and temperature.

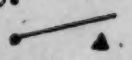
d. Current and voltage.

Answer to Frame 34: d

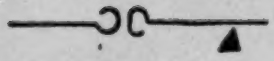
Frame 35

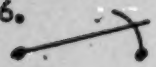
1.

2.

3. 

4.

5. 

6. 

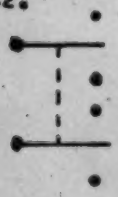
7.

8.

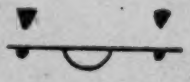
9.

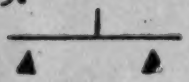
10.

11.

12. 

13.

14. 

15. 

16.

17.

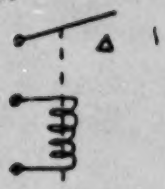
18.

19.

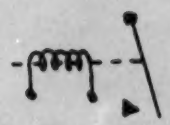
500

Frame 36

1.

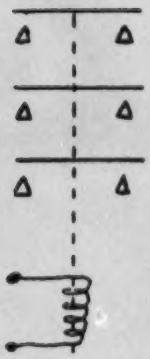


2.

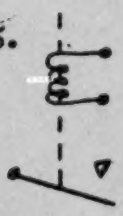


3.

4.



5.



6.

7.

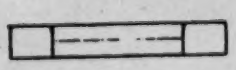
8.

9.

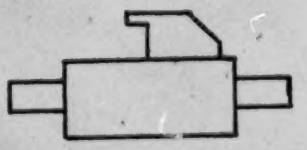
10.

11.

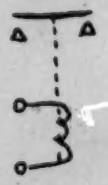
12.



13.



14.



506

PROGRAMMED TEXT
3ABR42335-PT-202
3ABR42331-PT-112

Technical Training

Aerospace Ground Equipment Mechanic
Aircraft Environmental Systems Mechanic

USE OF TEST EQUIPMENT
(PSM-37 MULTIMETER)

12 April 1977

3350 Technical Training Wing
3370th Technical Training Group
Chanute Air Force Base, Illinois

Designed for ATC Course Use.
Do Not Use on the Job.

502

FOREWORD

This programmed text was prepared for use in Course 3ABR42335, Aerospace Ground Equipment Mechanic. The materials contained herein were validated with 30 students from the subject course. At least 90% of the students passed the objectives as stated. The average time to complete this text was 543 minutes.

OBJECTIVE

Indicate the relationship of meter controls to their function and interpret meter scale indications with a minimum of 70% accuracy.

INSTRUCTIONS

This programmed text gives you information in small steps called "frames." Read and study the written material in each frame with care until you feel that you understand it. After each frame you are expected to respond by supplying a word, or words, to complete a sentence, choose either a true or false statement, select a correct answer, or match some terms to their locations or functions. After you have made your response, check your answers with the answers given at the bottom of the page of the next frame. If your answers are right, go on to the next frame. If you are wrong on any of your answers, read and study the material in that frame again and correct your mistakes before you go on to the next frame. If you still do not understand the material, ask your instructor for help.

Note: This programmed text is to be accomplished with the use of a PSM-37 multimeter and meter leads. Your instructor will provide you with these items.

INTRODUCTION

During your life you have used measuring devices. Some of these are clocks, rulers, speedometers, and weight scales.

As you read this PT you will learn about a measuring device used in electrical circuits. It is called a multimeter.

Supersedes 3ABR42335-PT-202, 14 October 1976, which may be used until all stock is depleted.
OPR: 3370 TTG
DISTRIBUTION: X
3370 TTGTC - 600; TTVSR - 1

The multimeter taught in this PT is the PSM-37 multimeter. The PSM-37 can be used to check alternating current (AC), direct current (DC), AC and DC voltage, and resistance. The maximum value of each that this meter can measure is given in the chart shown below.

Units	Without A Lead Adapter	With Adapter
Voltage	0-1000 Volts	0-5000 volts
Current	0-1 amp	0-10 amps
Resistance	0-100 Megohms	No Adapter

List the Five Functions of the PSM-37

1. _____
2. _____
3. _____
4. _____
5. _____

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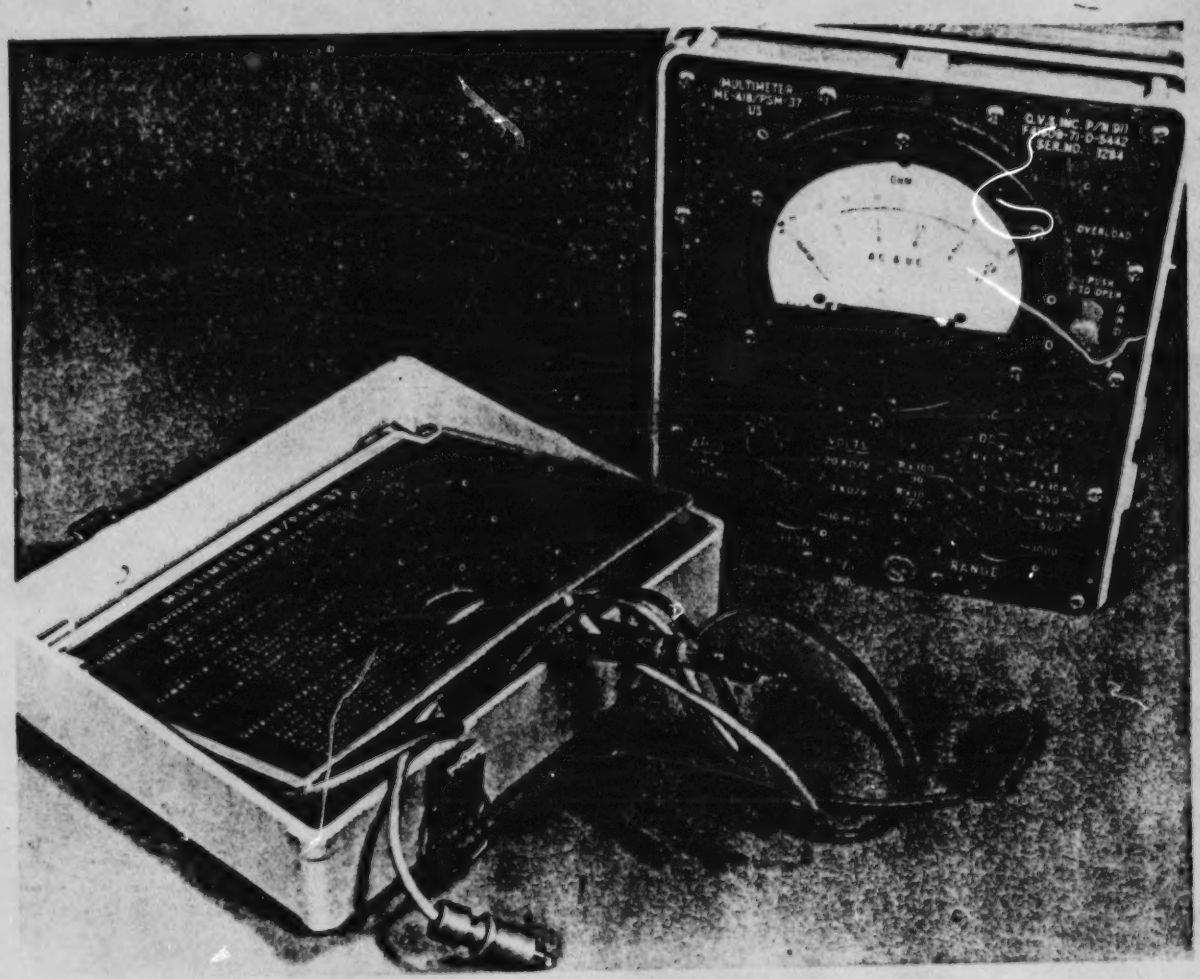
Frame 2

In order for you to make volts, amps and ohms tests with the PSM-37 multimeter, you must know where all of the controls are found and what they do. We will tell you about each of them in the next few frames. As we talk of them, find them on your meter to check your knowledge of their location.

NO RESPONSE REQUIRED.



Answers to Frame 1:

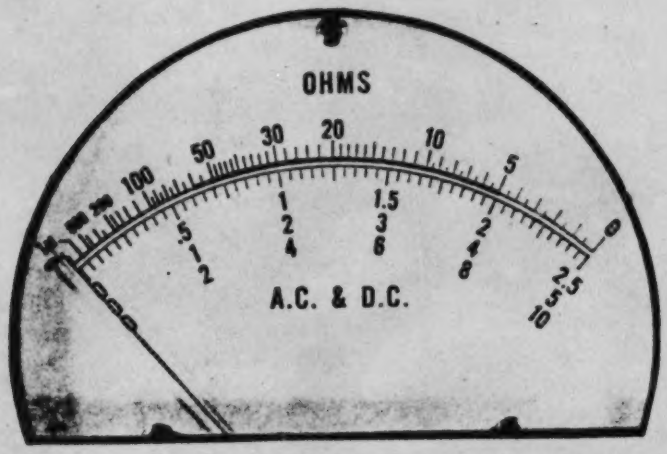
1. AC voltage, 2. DC voltage, 3. AC current, 4. DC current
5. Resistance (in any order).

The meter face shows the values that you are measuring. It is made up of two scales, OHMS and AC and DC.

The green OHMs scale is used when you make a resistance test. It is read from right to left. Look at your meter; you will see a wide green area on the OHMS scale from 5 to 60. The reason for this is to show the part of the scale where the most accurate readings can be made. In later frames you will find it extremely important in taking readings from this wide green area for the most accurate range.

The black AC & DC scale is used when you make a voltage or current test of circuits. The values of the scales will be volts when measuring voltage and milliamperes (MA) when you test for current. By now you should have seen that there are three sets of numbers below the black scale You will be told more about these later.

The meter needle (pointer) points to the value of volts, milliamperes or ohms being measured.



Match the statement or function in Column B with the names to which they relate to in Column A by placing the letter of the Column B items beside the numbers of the Column A items.

Column A		Column B	
_____1.	OHMS scale	a.	Read left to right and evenly marked.
_____2.	AC & DC scale	b.	Moves to indicate the value being measured.
_____3.	Needle	c.	Ranges from zero (0) to infinity (∞)
_____4.	Most accurate ohms range area		

d. Displays the values being measured.

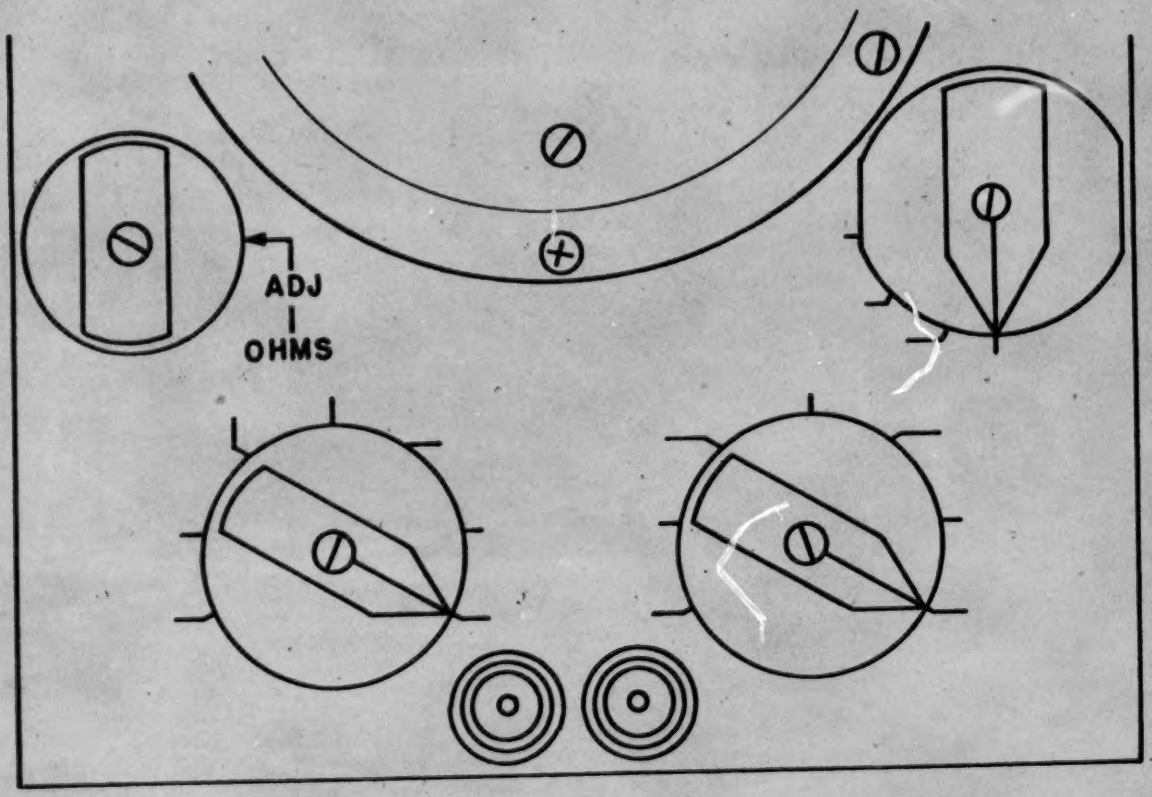
e. 0 to 60.

f. 5 to 60.

Frame 4

The OHMS ADJUST knob is found at the center and to the left of the meter front and is marked ADJ. It is used to compensate for the aging of the batteries that are in the meter. It is turned to make the needle line up on the "0" on the ohms scale, before you make a resistance check.

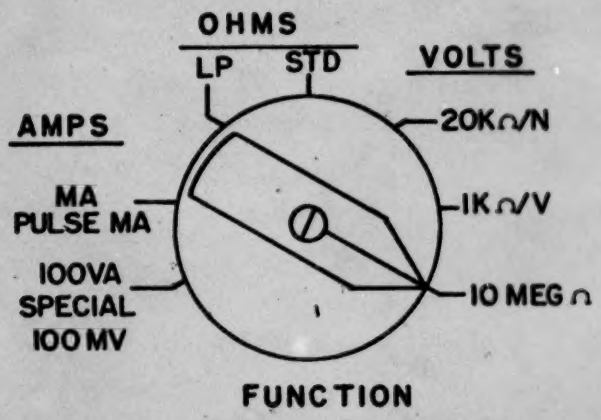
NO RESPONSE REQUIRED.



Answers to Frame 3:

1. c, 2. a, 3. b, 4. f

The FUNCTION switch can be seen in the lower left on the meter front. It is used to set the meter up to test for AMPS, OHMS, or VOLTS. It has seven positions. The ones that you will have to use the most are the "MA" position for current checks, "LP" and "STD" for resistance checks, and "10 meg Ω" for voltage checks. The "LP" position on ohms has a low power output for use when testing solid state devices and very small values of resistance (0 to 60 Ω). The "STD" is used for all other ohms checks.



Place a checkmark (✓) beside each true statement.

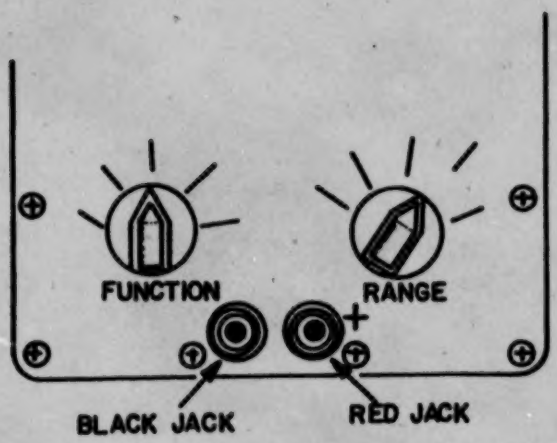
_____1. To set the meter for measuring voltage, you would turn the function switch to one of the voltage settings.

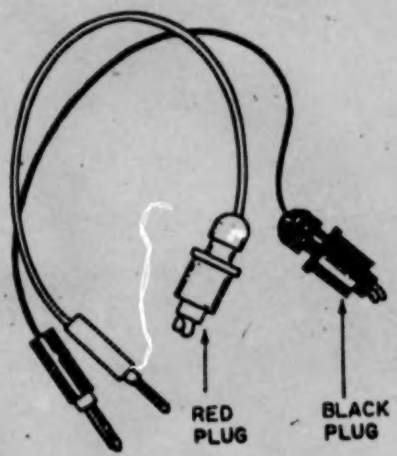
_____2. The "STD" position of the function switch is for measuring low powered components.

Frame 6

The test jacks are found at the bottom center of the meter front. The red one is the positive jack and is marked with a "+". The black jack is negative and is not marked. The two jacks give a connection point for the meter leads. There are two meter leads; one red and one black. The red lead will always be placed in the positive side of the circuit and the black in the negative. To put the meter leads in the test jack, do the following: slide the front part of the plug back while you push the plug into the jack. When you let go of the plug it will lock in place in the jack. Be sure that you match the color of the lead with the color of the jack. If you reverse the leads, the meter may be damaged when it is connected to a live circuit (one that has power in it). Refer to the diagram below.

Note: Place your meter leads in the test jacks of your meter at this time (the leads are normally stored in the meter lid).





Complete the following statement(s) by choosing the correct word or words and record on the response sheet.

1. The red lead is _____ (negative-positive) and is connected to the _____ (red-black) meter jack. The _____ (red-black) negative lead is connected to the _____ (red-black) meter jack.

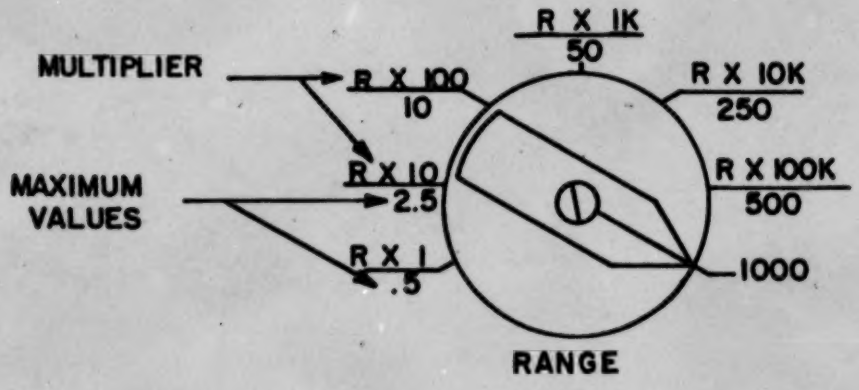
Answers to Frame 5: ✓ 1. _____ 2.

The RANGE switch is found in the lower right corner of the meter front and is marked RANGE. It is used to set the maximum values of voltage and current to be measured or, the multiplier for the resistance checks. The maximum range settings are those numbers below the lines. The multiplier are the R X numbers above the line. The position of the range switch relates one of three things to the operator:

1. The maximum voltage that the meter can measure at that particular range setting. Set the function selector to the volts - 10 Meg position and the range switch to the 10 position. The meter will measure a maximum of 10 volts.

2. The maximum current that the meter can measure at that particular range setting. Set the function selector to AMPS - MA and the range switch to 500. The meter is capable of measuring a maximum of 500 ma (one-half of an amp).

3. The multiplier of the ohmic (resistance) value that the meter is reading. Set the function selector to the OHMS - STD position and the range switch to R X 1K. Multiply the meter reading by 1000 to get the correct resistance value.



Place a "T" in the space provided beside each true statement.

____1. The range switch means the maximum voltage the meter will measure on the OHMS function.

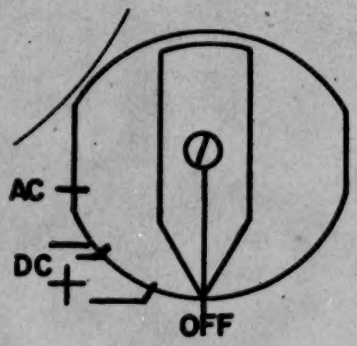
____2. While the PSM-37 is set to AMPS - MA, the range switch tells the operator the maximum current the meter is capable of measuring at that setting.

____3. With the RANGE switch in the R X 10K/250 setting, the operator would multiply the OHMS scale readings by 10,000.

Answers to Frame 6: 1. positive, red, black, black

Frame 8

The polarity switch turns the multimeter on and off, and sets the meter to test DC+, DC-, or AC. The "+" and "-" signs mean the polarity that must be applied to the red test lead when you make DC measurements so that the meter pointer will move up scale to the right. If the pointer moves to the left, just change the polarity switch to the other DC setting or reverse the test leads in the circuit. When you make OHMS checks, the + or - will mean the output polarity of the red test lead. The shape of the polarity switch knob will not allow the cover for the meter to be put on unless the switch is in the off position.



Complete the following statements by placing the correct word(s) in the blank spaces.

1. When a negative voltage is applied to the red lead, the polarity switch must be turned to the _____ position.

2. The meter polarity switch would be turned to _____ position when measuring alternating current.

3. If the meter needle moves to the left of the "0" on AC & DC scale, the _____ switch must be turned to the opposite DC position.

Answers to Frame 7: ____1. __T__2. __T__3.

The OVERLOAD indicator, and the PUSH TO OPEN AND RESET control are both a part of the overload protection circuit. A red shaft will show in the overload indicator when the meter has been overloaded. To reset the meter for normal use, just take the meter leads out of the circuit, and push the "push to open and reset" control. The red shaft will retract and stay that way when you let go of the button, if the overload circuit breaker has been reset the right way. The next step is to set the meter to a higher range so that it will not be overloaded again. Now the meter is ready for use. The push to open and reset control should be pushed in when you change the range or function switch setting and you do not take the test leads from the circuit.

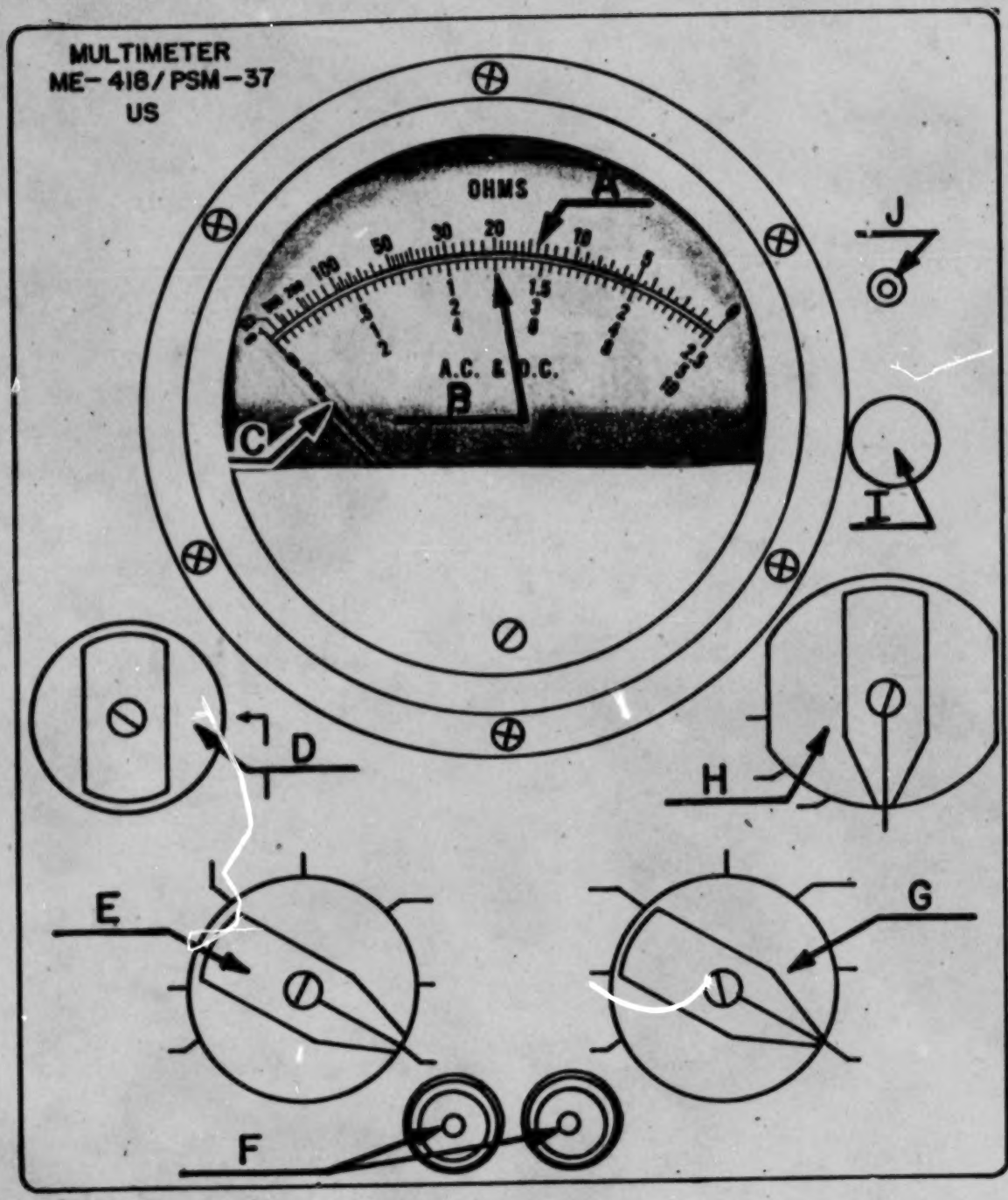
Complete the statements below by filling in the blank spaces with the correct answers.

1. If too much voltage or current is applied to the meter, the _____ indicator will have a _____ shaft appear in it.

2. After removing the meter from a circuit due to an overload, you must push in the _____ button.

Answers to Frame 8:

1. DC-, 2. AC, 3. Polarity



This illustration is to be used with the meter controls and function exercise on the next page.

The following exercise checks your knowledge of the meter control names, location and functions. Use the illustration of the meter on the preceding page to select the letter that corresponds to the name of that control. Place the letter you chose from the illustration in the "Meter Letter" column. Then match up the function of the controls in the "Function" column with the name of the control in the "Name" column. Place your letter choice in the "Function Letter" column.

	Name	Meter Letter	Function Letter
1.	Needle (Pointer)	C	(b)
2.	OHMS (Green)		( )
3.	OHMS Adj.		( )
4.	Test jacks		( )
5.	Function switch		( )
6.	Polarity Switch		( )
7.	PRESS TO OPEN and RESET		( )
8.	AC & DC		( )
9.	Overload		( )
10.	Range Switch		( )

Functions

(a) scale used to indicate voltage or current readings.

(b) aligns with the scale to indicate value measured.

(c) hook-up point for leads.

(d) used to break meter input circuit and reset overload protector.

(e) used to "zero" the pointer on OHMS scale.

(f) determines if meter measures OHMS, VOLTS, or AMPS.

(g) used to select the type of current or voltage to be applied to the meter.

(h) indicates values in OHMS.

(i) determines maximum value to be measured or multiplier for ohms.

(j) indicates excessive power has been applied to PSM-37.

Answers to Frame 9:

1. overload, red
2. Push to open and reset

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The PSM-37 meter is built to measure many OHMS values. A look at the meter in front of you shows that there are six (6) positions for the ohmmeter function. They are R X 1, R X 10, R X 100, R X 1K, R X 10K and R X 100K. To measure resistance, the POLARITY switch must be turned to one of the DC positions (usually DC+); the RANGE switch must be set to one of the six positions listed above and the function switch must be set on OHMS. The OHMS position used in this block will be the STD position. (NOTE: The LP position is for testing low power devices and is used with the R X 1 position of the RANGE switch.) To measure resistance accurately, the ohmmeter must first be "zeroed". You zero the meter by touching the ends of the leads together with the meter set as you were told above. The meter needle should move to the zero end of the ohms scale. Note that the OHMS scale is GREEN. If the needle does not go all the way to zero, or goes past, then turn the OHMS ADJ knob. Turn the knob to bring the needle in line over the "zero" on the OHMS scale. When the test leads are separated the needle should go back to the left end of the OHMS scale, over the infinity (∞) mark.

Use your PSM-37 and zero the ohmmeter in the R X 10 through R X 100K range positions.

Note: The PSM-37 meter should not need to be rezeroed on each of the RANGE switch positions. Once zeroed, the meter should stay zeroed through all resistance range positions.

If your meter will not zero on any of the ranges, push the "Push to Open and Reset" button. If your meter still will not zero, ask your instructor for help.

Check the true statement(s).

_____1. With the function switch in OHMS STD and RANGE switch in R X 1, the meter can be zeroed on OHMS. (Use your meter and test this statement.)

_____2. The readings are taken from the green scale of the PSM-37 when the function switch is in the OHMS function.

_____3. The PSM-37 meter needs only to be zeroed when you first start to use it as an ohmmeter.

_____4. The zero mark for OHMS is on the left side of the OHMS scale.

Answers to Frame 10: 1. C (b) 2. A (h) 3. D (e)
4. F (c) 5. E (f) 6. H (g) 7. I (d)
8. B (a) 9. J (j) 10. G (i)

The OHMS (green) scale is probably the most easy to read. The value of each mark on the scale stays the same for each position of the RANGE switch. For example, the numbers on the OHMS scale will always be the same value; 5, 10, 20, 30, and so on. The range switch is what determines what you multiply these numbers by to get the resistance reading of what you are measuring. This will be covered in the next frame.

You will not have much trouble with reading the meter when the meter's needle comes to rest on one of the larger marks which are numbered, or when the needle comes to rest halfway between any two numbered marks. The hard part comes when the needle comes to rest on a small mark or between small marks. To find the small mark values follow these steps:

1. First step, note the two numbered values which the needle is resting between.

2. Subtract the smaller value from the larger value.

3. Count the number of divisions (blank spaces) between the two numbers.

4. Divide the value you got in step two by the number of divisions counted in step three.

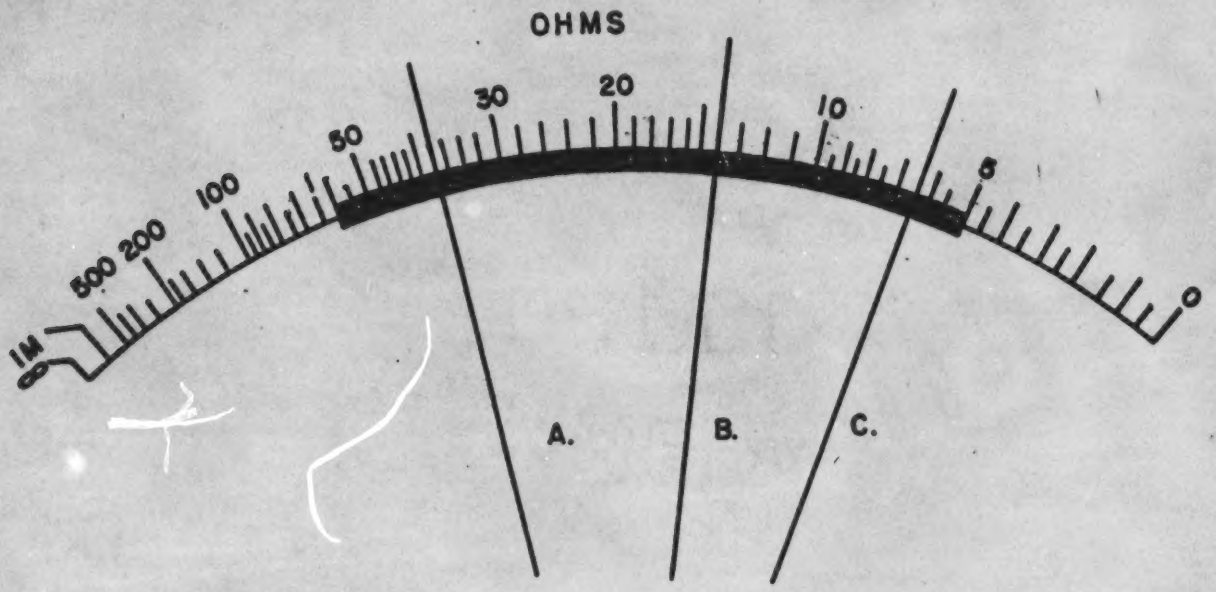
5. You now have the value of one division on the scale you are using.

6. Add up the number of divisions your needle is from the lowest value you noted in step one.

7. The last step is to add the total value of the summed divisions in step six to the lowest number value to get the proper reading.

As an example of the procedure outlined above, we will go through the complete procedure for the value indicated by pointer A in the figure on the next page.

Frame 12 (continued)



1. Needle is resting between 30 and 50.

2. Subtract 30 from 50 you get 20.

3. Count 10 divisions between 30 and 50.

4. Divide 20 (from step 2) by 10 to get 2.

5. One division is equal to 2.

6. The lowest value is 30 and the needle is four divisions to left of this value.

7. Multiply 4 times 2 to get 8; add 8 to 30 to get 38.

Using the figure above, complete the following by filling in the blank with the correct response.

1. Needle B is indicating _____.

2. Needle C is indicating _____.

3. Each division mark between 20 and 30 is equal to _____.

4. Each division mark between 50 and 100 is equal to _____.

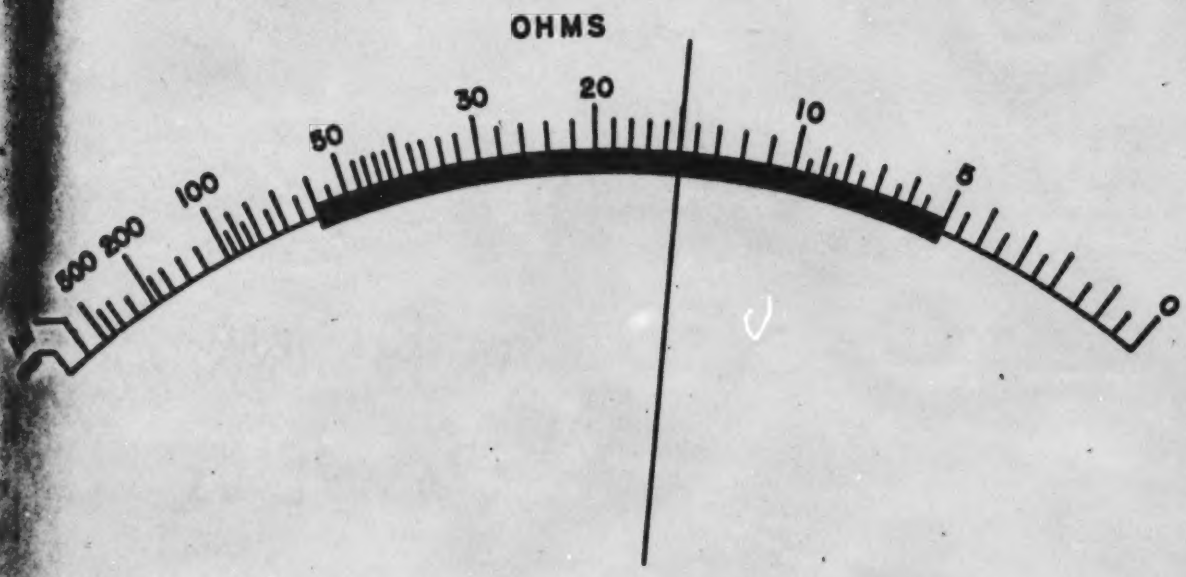
Answers to Frame 11: ____1. ✓ 2. ✓ 3. ____4.

The illustration below shows the ohmmeter scale of the PSM-37. When measuring resistance in the R X 1 range, it is read just as is shown by the needle on the OHMS scale. With the RANGE switch in any of the other R X positions you would multiply the resistance reading (R) times the number at the R X position.

Example: In the R X 10 position the needle stops at the 30 mark on the OHMS scale. You would take 30 times 10. The ohmic value you have measured is 300 ohms. In the R X 100 position it would be 30 times 100, which equals 3000 ohms.

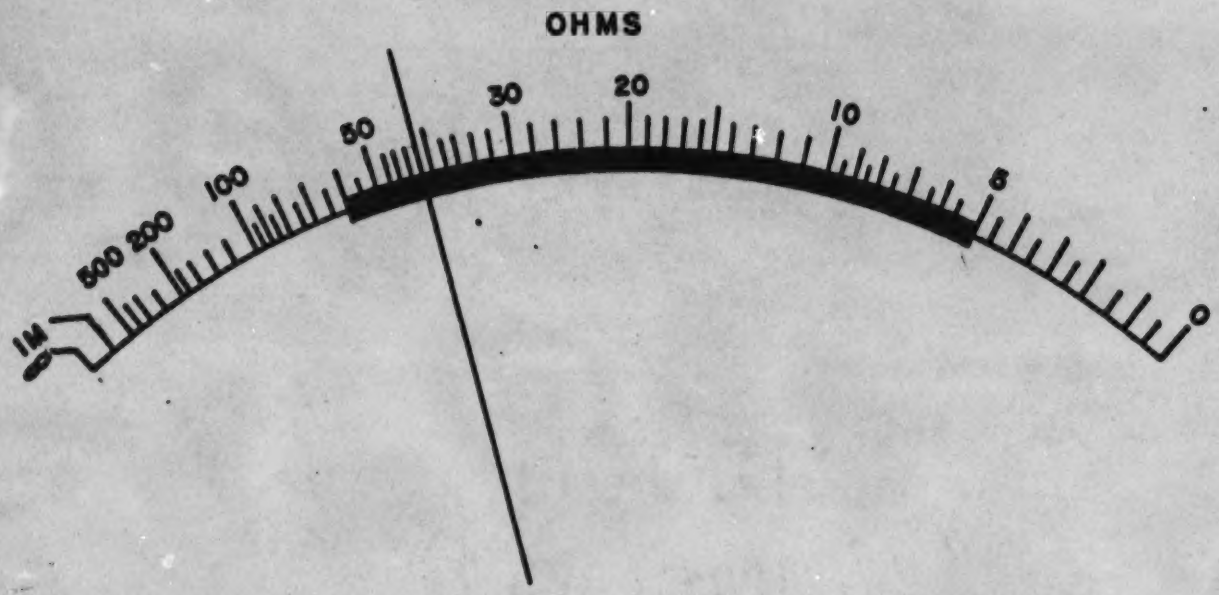
What resistance is indicated in each of the ohmmeter scales below?

1. R X 10 = _____

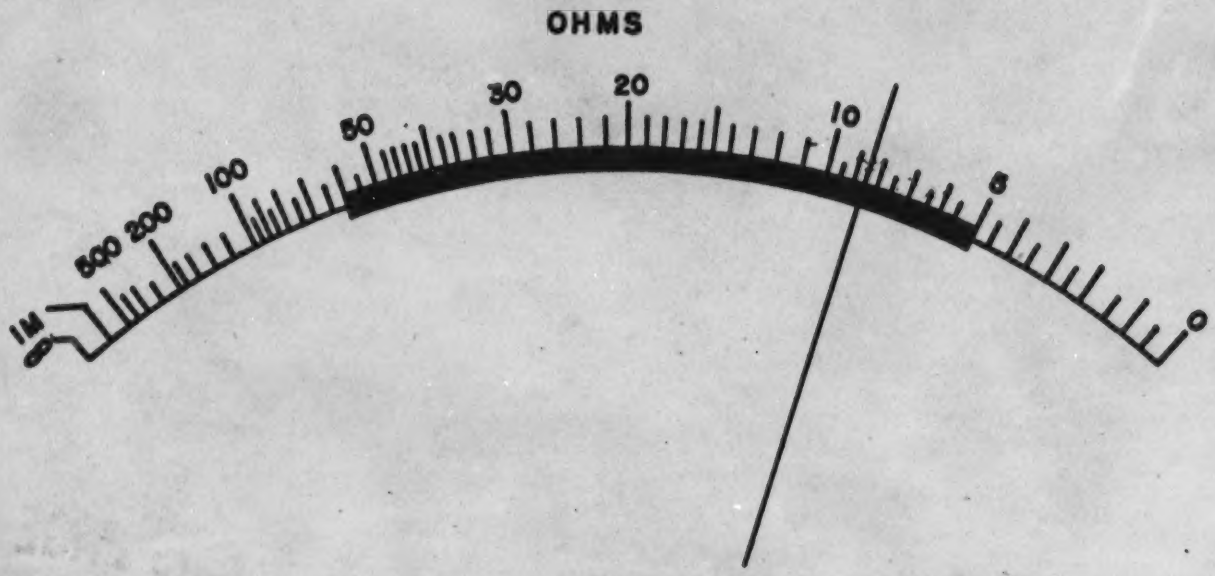


Frame 13 (continued)

2. R X 10K = _____

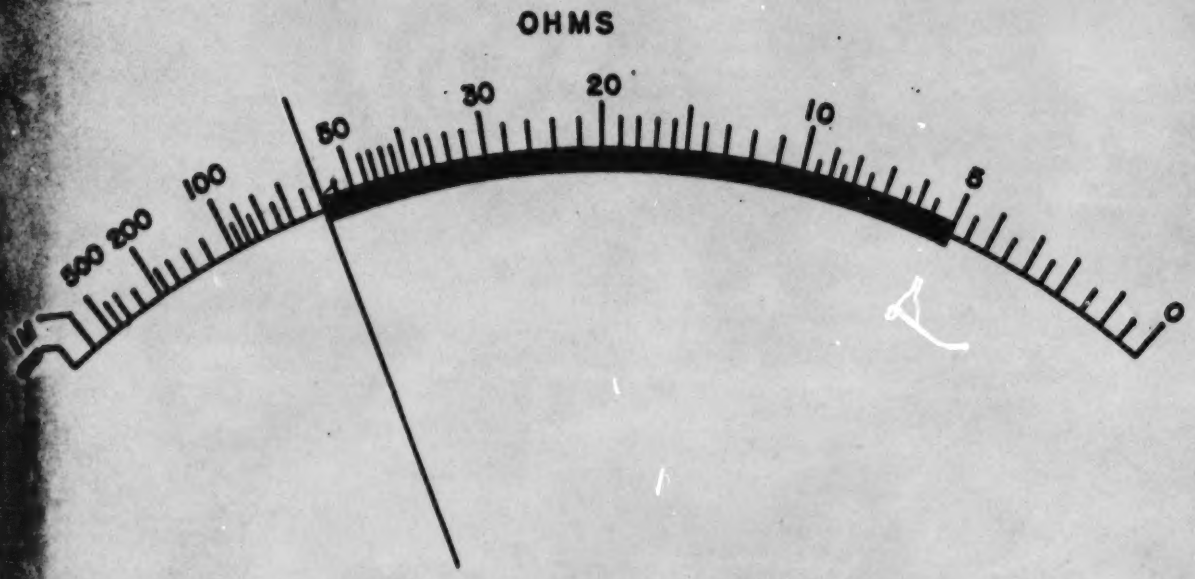


3. R X 1K = _____



Frame 13 (continued)

4. R X 1 = _____



Answers to Frame 12: 1. 14 2. 6.5 3. 2 4. 5

520

Frame 14

The range to be used in measuring any resistance that you do not know depends on the ohmic value of the unknown resistance. Let us say that the R X 1 range of the PSM-37 is being used and that the unknown resistance that you have is more than 2,000 ohms. In this case the resistance is too great to move the pointer away from infinity (∞). The RANGE switch would then have to be set to the R X 10 position. If this was done and the needle still did not move, then you would have to use the R X 100 range, and so on. If the needle still does not move when you use the R X 100 range, you have a resistance that is too high to measure with the PSM-37. This is commonly referred to as an infinite amount of resistance and is represented by "∞".

Note: To be sure no problem exists with the meter, check to see if the meter will zero in all resistance range positions.

Check the true statement(s).

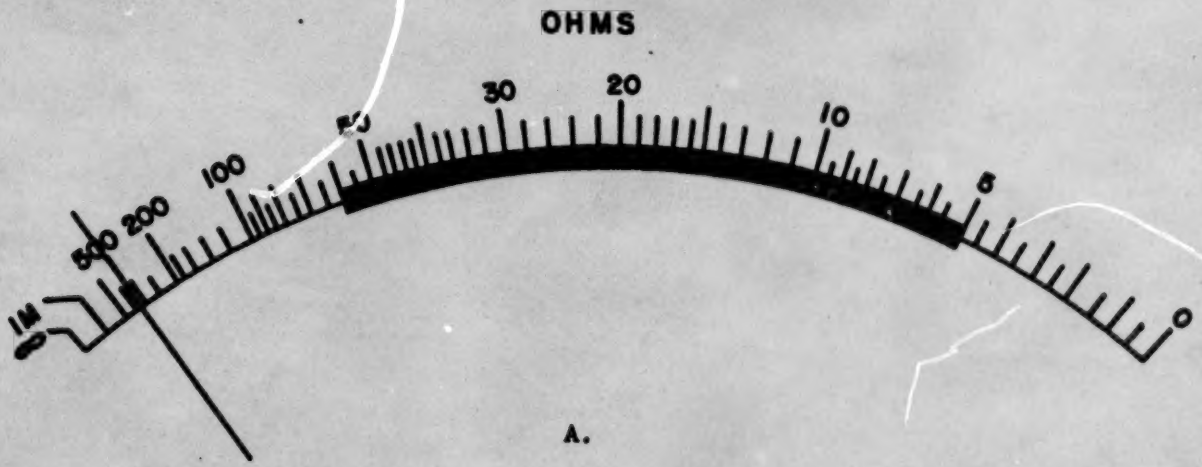
_____1. A resistance reading of ∞ is the same as one of 0 ohms.

_____2. When testing resistance, if the needle of the ohmmeter doesn't move, it is indicating infinity (∞).

Answers to Frame 13: 1. 150Ω 2. 420,000Ω 3. 8,500Ω

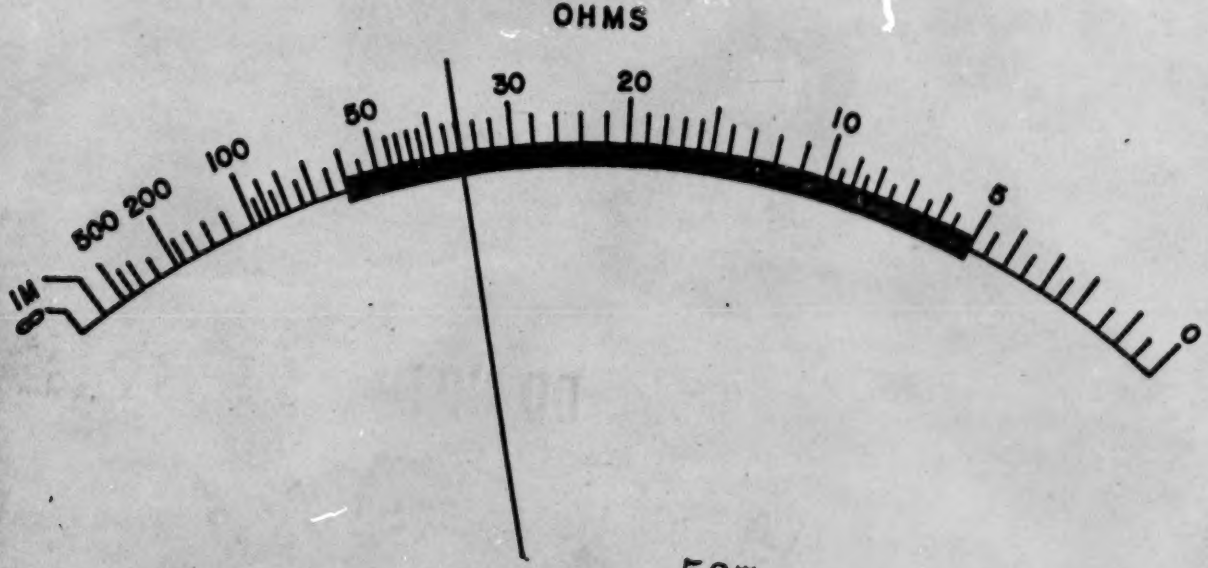
4. 60Ω

When you use the PSM-37 to check ohms, set the RANGE switch to a position where the needle rests in the wide green area of the OHMS scale. Try not to take the readings from any other part of the scale, if it is possible. We need to do this because the ohmmeter is less accurate from ∞ to 5 and 60 to ∞. In example A, a resistor with an ohmic value of 360 ohms is being measured with the range switch in the R X 1 range. The meter needle is between the 300 to 400 marks, a difference of 100 ohms. Since the operator is forced to guess at the reading, a large margin for error can exist.



A.

Example B shows the same resistance measured using the R X 10 range. Even though the operator must multiply the scale reading by 10, the reading is more accurate because each mark in this area of the scale is 20 ohms (marks are 2 points each time 10, equals 20). Then, the margin for error is reduced.

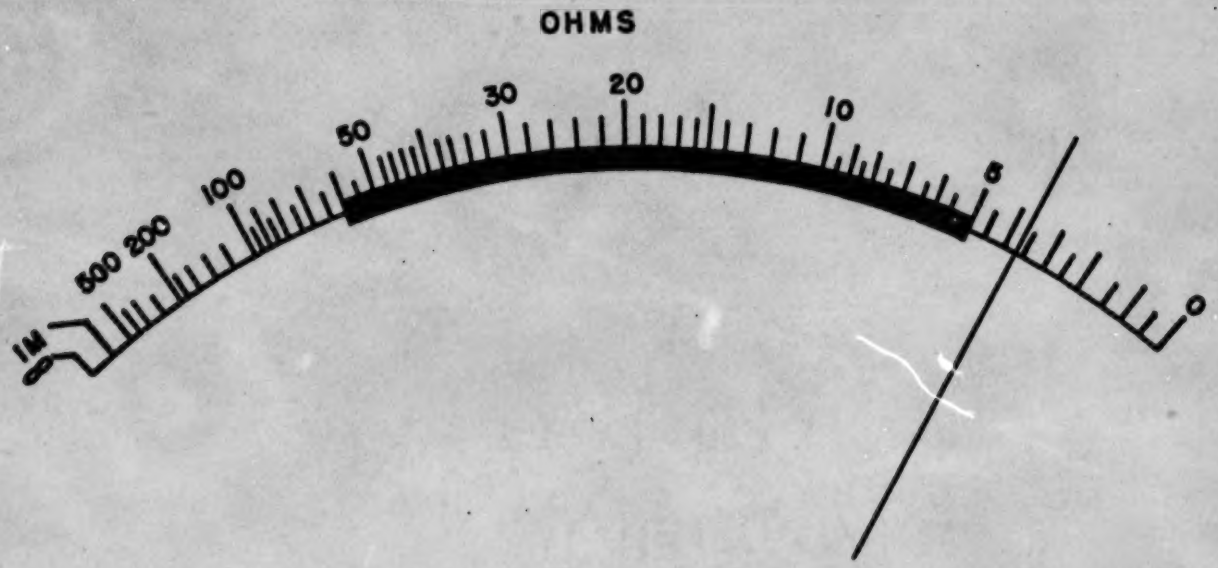


B.

527

Frame 15 (continued)

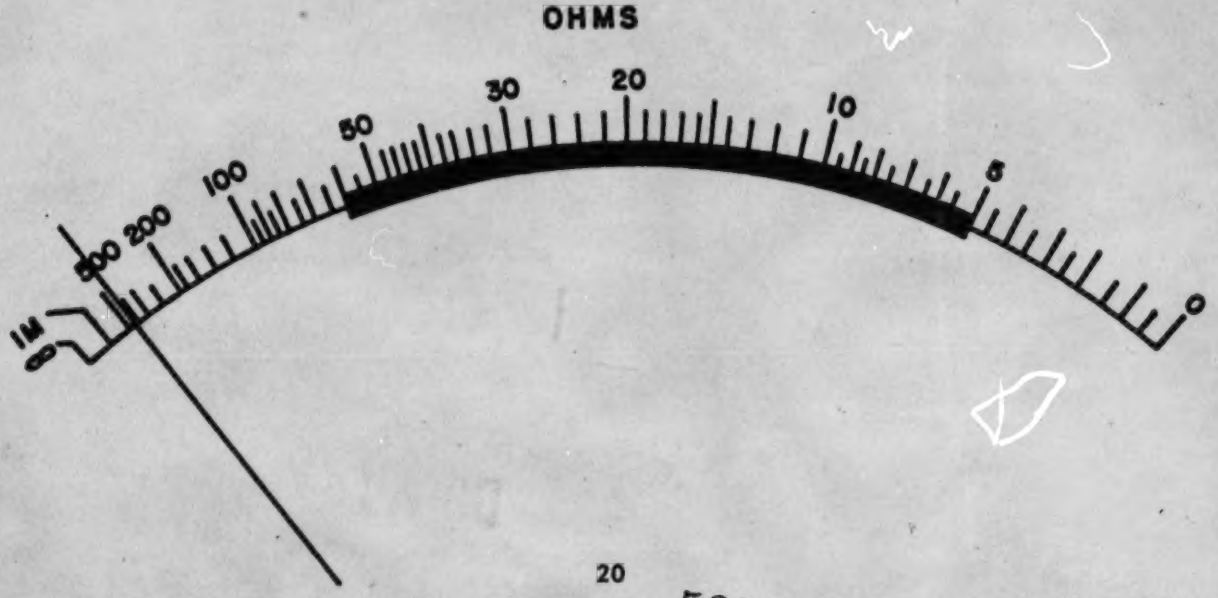
Example C shows a 360 ohm resistance reading on the R X 100 range. In this case you must multiply the scale reading by 100. The measurement is less accurate than B because each mark is worth 50 ohms (.5 X 100 equals 50). The margin for error is increased.



C.

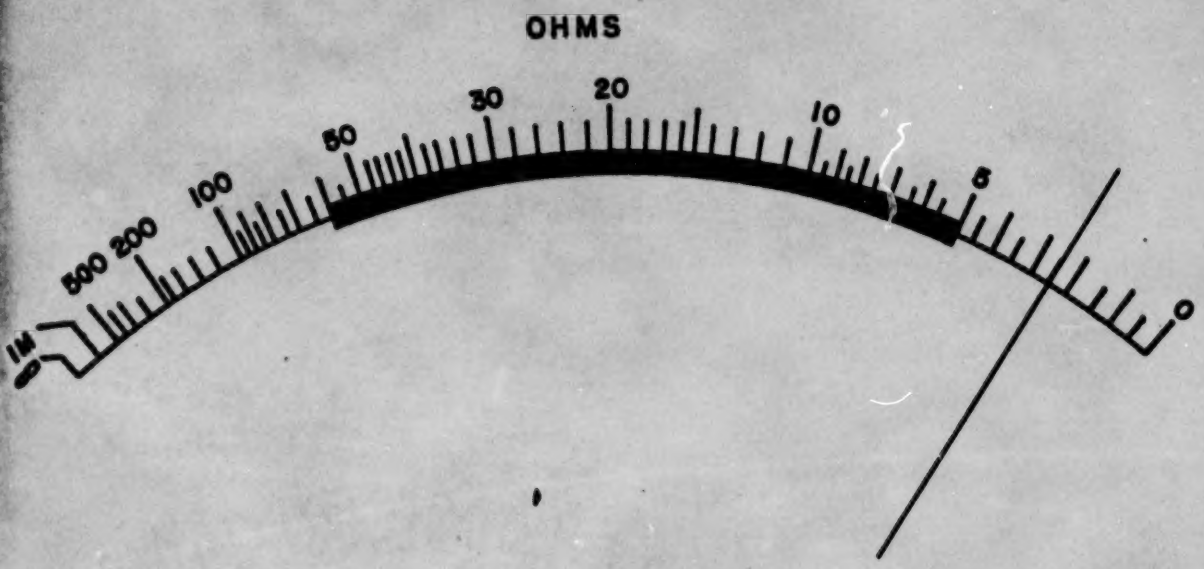
Study the ohmmeter scales shown below. Find out if the resistance is being read by the most accurate range. If the right range is used, write "OK" in the blank next to that scale. If the right range is not used, write the range which should be used.

1. 480 ohms, R X 1 range _____.

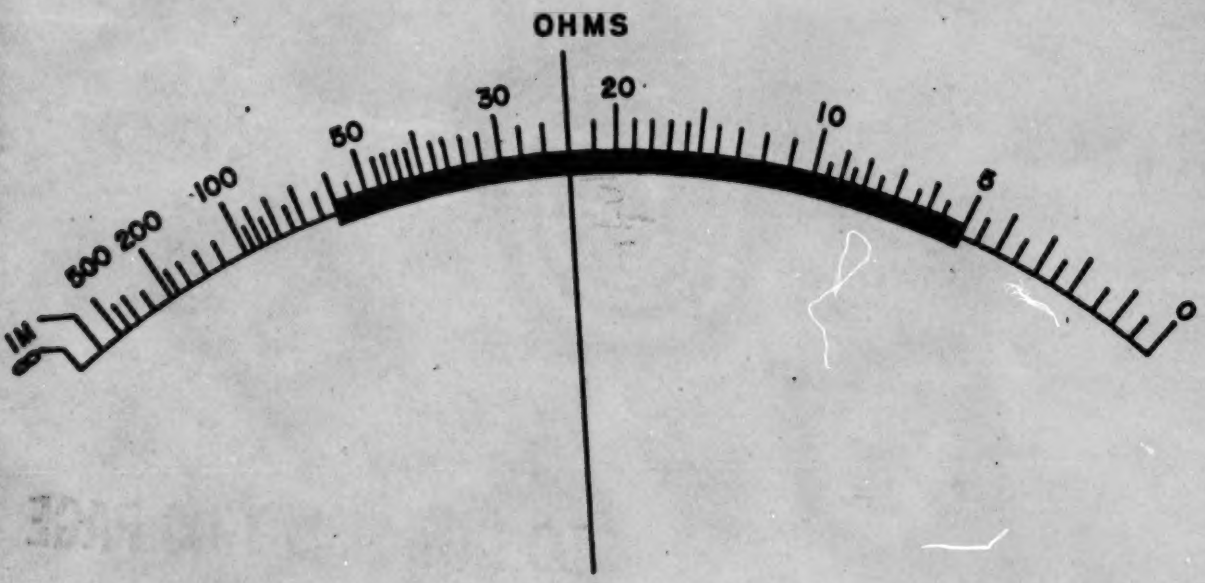


Frame 15 (continued)

2. 25 ohms, R X 10 range _____.



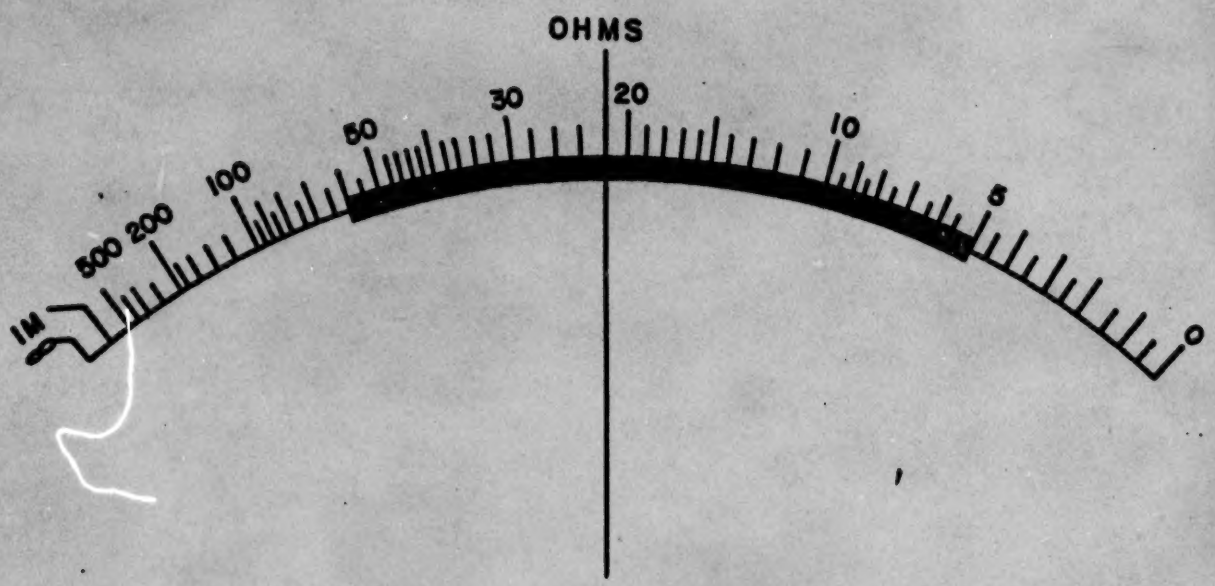
3. 240 ohms, R X 10 range _____.



529

Frame 15 (continued)

4. 2200 ohms, R X 100 _____.



Answers to Frame 14: ____1. ___✓__ 2.

Look at the face of the PSM-37 meter in front of you. The AC & DC scales are printed in black. On the lower left side of the meter face you will find the FUNCTION switch. It has three VOLTS positions. While in this block we will have you use the 10 meg Ω position. The only difference between the three positions is in circuit loading and this is of no importance to you at this point. On the lower right side of the meter face is the RANGE switch. This switch is very important since it is used to select the maximum range the meter can measure in volts and current. If you select the wrong range, you could cause damage to the meter.

Look at the AC & DC scale. You will notice that there are three sets of numbers. In the space below, write the range for each set of numbers. The first one has been done for you.

Top Scale: Numbers range from 0 to 2.5.

Middle Scale: Numbers range from _____ to _____.

Bottom Scale: Numbers range from _____ to _____.

Answers to Frame 15: 1. R X 10 2. R X 1 3. OK 4. OK

Frame 17

The number to the far right of each scale shows the maximum deflection of the meter's needle. The values of these numbers (2.5, 5, and 10) will depend on where the range switch is set. There are seven ways to set the range switch: .5, 2.5, 10, 50, 250, 500 and 1,000. These numbers show the highest value which can be read with the meter for any of the settings of the range switch. For example, if the range switch was set at 250, the maximum value that could be checked with the meter would be 250. This value may be in volts or milliamps as determined by the function switch. If more than 250 were applied to the meter, it might be hurt.

Fill in the blanks with the correct number.

1. If the range switch is set at 50, the maximum voltage that can be measured would be _____.

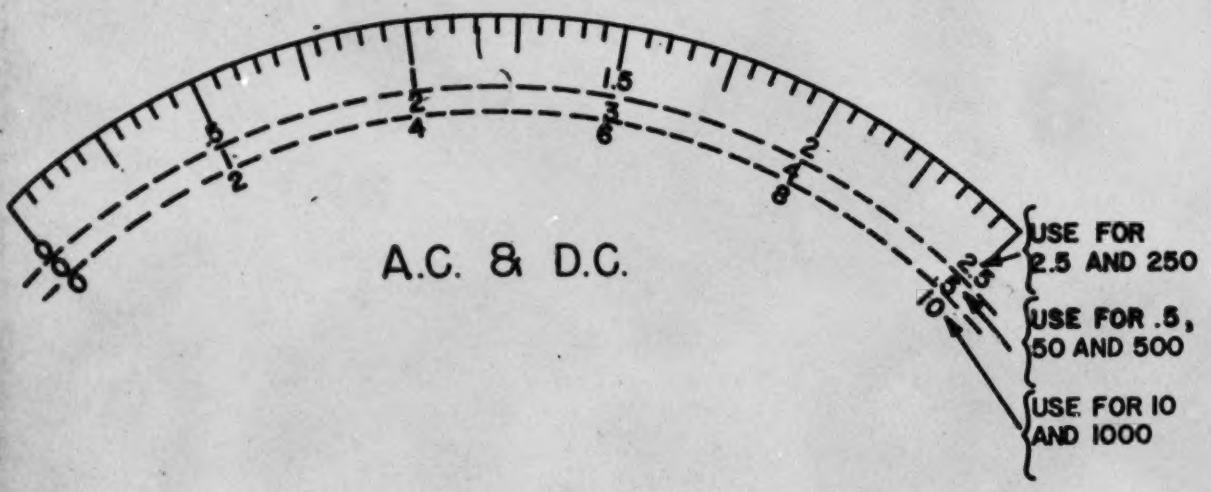
2. If the range switch is set at 2.5, the maximum voltage that can be measured would be _____.

3. If you wanted to measure a voltage, the value which would be between 250V and 500V, the RANGE switch would have to be set at the _____ position.

Answers to Frame 16: 0 to 5

0 to 10

Since there are seven ways to set the range switch and only three different scales, each scale is used by several range positions. The 2.5 and 250 range switch positions use the top scale (0-2.5). The .5, 50, and 500 ranges use the middle scale (0-5). The 10-100 range use the bottom scale (0-10). Do not try to memorize these as they are easy to figure out.



Place either 0-2.5 or 0-5, or 0-10 in the spaces provided to indicate the scale that would be used for each of the range switch settings. The first one has already been done for you.

Range Switch Set at		Scale Used
.5	a.	0-5
2.5	b.	_____
10	c.	_____
50	d.	_____
250	e.	_____
500	f.	_____
1000	g.	_____

Answers to Frame 17: 1. 50V 2. 2.5V 3. 500V

Frame 19

In the last frame you learned how to choose the right scale for each range position. With the RANGE switch set on 50, the readings are read from the 0-5 scale. Since the meter can now only read a maximum of 50, the number 5 will mean 50. The 4 will mean 40, the 3 will mean 30, and so on. Notice that the changing of 5 to 50 resulted in the maximum number on the scale matching the RANGE switch position, and the other numbers change by the same amount (multiplied by 10). The way to determine the value of the maximum number on the scale is: it must be changed to equal the range switch position. Example: The range position of 250 uses the 0-2.5 scale. The 2.5 will now mean 250, the 2 will mean 200, the 1.5 will mean 150, and so on.

For all the exercises below, the POLARITY switch is set on "DC+," the FUNCTION switch is set on 10 meg VOLTS. What is the voltage indicated on each of the following scales for each of the RANGE switch positions? The first one is completed for you.

1. Use figure A.

   a. 50 range 40V DC

   b. 1000 range _____

   c. 500 range _____

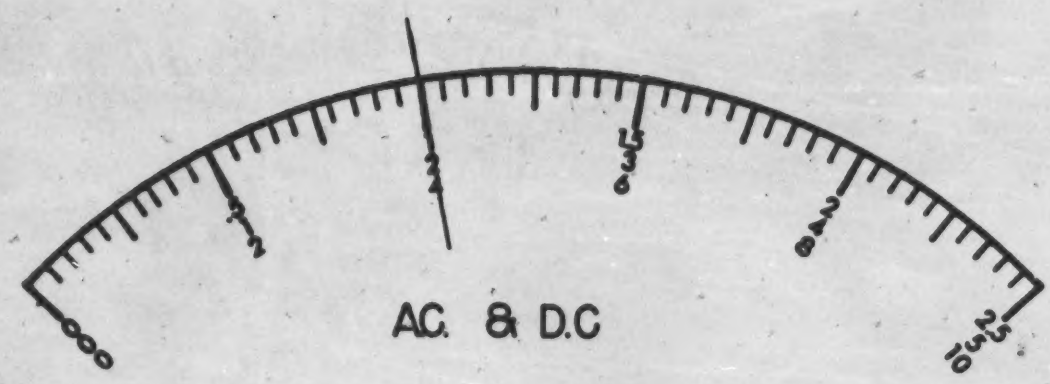
   d. .5 range _____

Frame 19 (continued)

2. Use figure B.

a. 2.5 range _____ c. 250 range _____

b. 10 range _____ d. .5 range _____

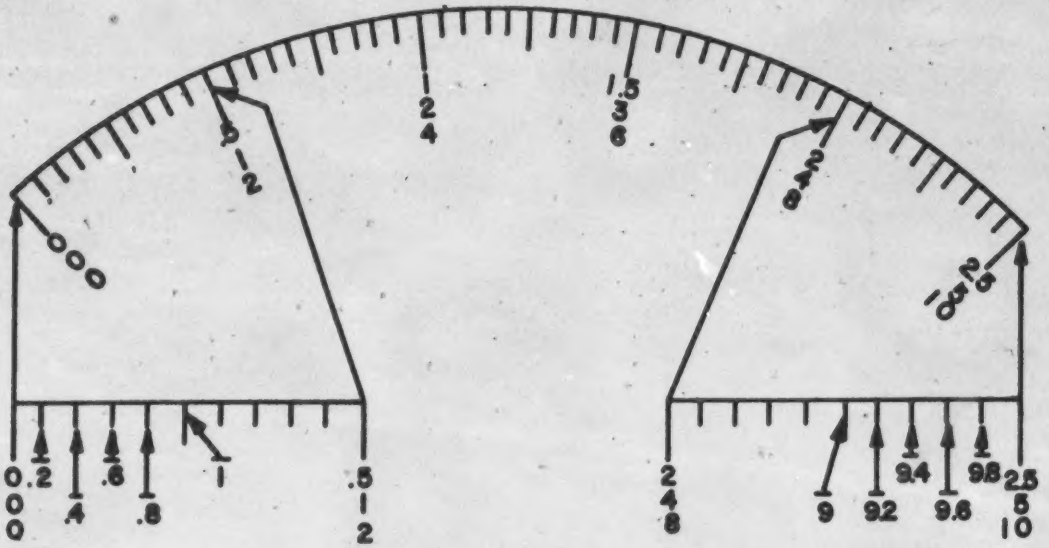


Answers to Frame 18: b. 0-2.5 c. 0-10 d. 0-5

e. 0-2.5 f. 0-5 g. 0-10

530
Frame 20

The maximum value of each scale is determined by the position of the RANGE switch. With the RANGE switch at the 10 range, the 0-10 scale was read as is, Max 10. The difficulty in reading the scale comes when the needle stops on one of the small marks between the numbers. <u>To find the value of each mark on the scale, divide the RANGE switch position by 50</u>. Example: RANGE switch in 10 range, divide 10 by 50 to get .2. Each marking on the 0-10 scale is worth .2 points a piece. See figure A below. When you start at zero, you would count the marks, 0, .2, .4, .6, .8, 1 - - - - - - - - - 9.2, 9.4, 9.6, 9.8, 10. You use the same procedure to find the value of the small mark for each of the RANGE switch positions. The reason we use 50 as the denominator is there are 50 marks along the AC & DC scale. Since the scale is linear (evenly spaced and marked), you can use the 50 as the denominator on all range positions and scales.



PROBLEM 1

Fill in the blanks with the appropriate response for the scale used and the value of each black mark on the scale. The first one is accomplished for you.

Range Switch Set At		Scale Used		Value of Each Mark
.5		0-5		.01
2.5	a.	_____	b.	_____
10	c.	_____	d.	_____
50	e.	_____	f.	_____
250	g.	_____	h.	_____
500	i.	_____	j.	_____
1000	k.	_____	l.	_____

Answers to Frame 19:

1. b. 800V DC c. 400V DC d. .4V DC

2. a. 1V DC b. 4V DC c. 100V DC d. .2V DC

Frame 21

The following exercise is to insure your ability to interpret meter indications in various RANGE switch position , plus check your ability to determine the value of each mark on the meter scales. Fill in the correct answer in the appropriate space for each of the following items. Number one is completed for you.

Range Switch Set At		Value Indicated
1.	.5	.37
2.	2.5	
3.	10	
4.	50	
5.	250	
6.	500	
7.	1000	

Answers to Frame 20: a. 0-2.5 b. .05 c. 0-10 d. .2 e. 0-5 f. 1. g. 0-2.5 h. 5. i. 0-5 j. 10 k. 0-10 l. 20

Frame 22

You now know how to read the scales and its values, with the range switch set in any of the ranges. What you have learned will be true even if the meter is measuring AC or DC voltage or current. In the next few frames you will learn how to set the meter up to read DC volts, AC volts, DC current and AC current. It is important that you know the positions of the three switches, so you can tell what the meter is reading. The switches are: The POLARITY switch to tell if you are measuring + or - DC or AC volts, or current; the FUNCTION switch to tell if you are measuring voltage (VOLTS position), resistance (OHMS position), or current (AMPS position); the RANGE switch to tell you the maximum value and scale to be used for the readings.

Place a checkmark (✓) beside the true statement(s).

_____1. To measure OHMS, the polarity switch would be on either DC position, the function switch to OHMS, and the range switch to appropriate R X position.

_____2. To measure a 30 volt battery, the polarity switch would be in +DC, the FUNCTION switch to VOLTS, and the RANGE switch to R X 1K/50 position.

Answers to Frame 21: 2. 1.85 3. 7.4 4. 37 5. 185

6. 370 7. 740

534

Frame 23

When you want to read DC voltage it is important to have the meter set up right. The FUNCTION switch set to VOLTS (in school, 10 meg Ω position); the POLARITY switch set to the polarity of the voltage applied to the RED test lead; (Note: In most cases, this will be positive and the polarity switch will be set at "DC+".) the RANGE switch will be set to the value of the voltage to be read. For example, if the voltage to be read is 8 volts DC, the RANGE switch would be set at 10. It is important to keep in mind the range switch sets the maximum value the meter can read; so, set the RANGE switch above the value to be read. When you want to read an unknown voltage, start with the range switch at the highest value. Then, turn the RANGE switch to a lower setting until the meter shows a voltage value. This procedure is a good practice to follow, regardless of what you are measuring.

Fill in the blanks with the correct switch position. For practice, set your meter up to measure the voltage in problem number one.

1. If you knew that you were going to measure approximately 120 volts DC, the RANGE switch would be set at _____, the POLARITY switch set at DC+ and the FUNCTION switch set at _____.

2. If you didn't know the approximate value of the voltage that you were measuring, you would use the _____ range first.

3. A negative voltage polarity is applied to the RED test lead, the POLARITY switch would be set at _____.

Answers to Frame 22: ✓ 1. ✓ 2.

When you use a voltmeter, you have to be sure the readings are as true as you can get them. Always choose the RANGE switch position which will cause the meter needle to move as close to a full scale reading as you can. For example, you could read 2 volts DC on the PSM-37 in front of you by setting the RANGE switch on 10 and read the voltage value off the bottom scale (0-10). But, it would be better if you set the RANGE switch to 2.5 and read the voltage on the top scale (0-2.5). By doing this, you can get more needle deflection than if you had set the RANGE switch on 10.

Fill in the blanks with the correct positions.

1. Look at the meter in front of you. If you were going to measure approximately 300V, you would have to set the range switch at _____ to get the most accurate reading.

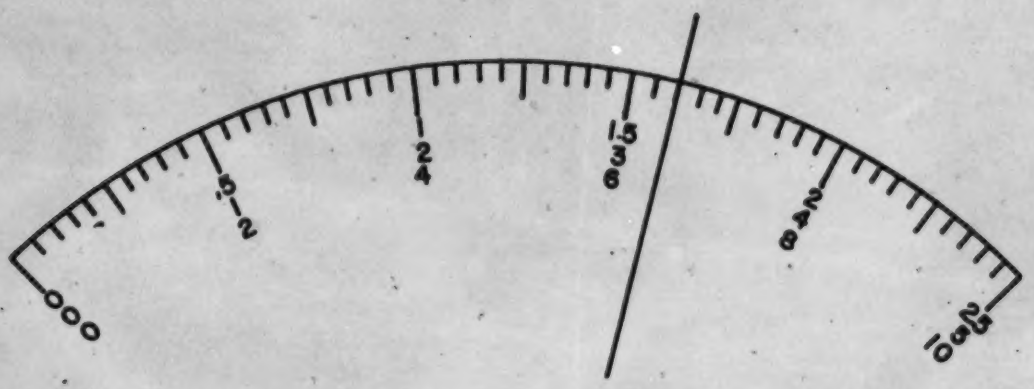
2. If you wanted to accurately measure 30V, you would have to set the range switch at _____.

Answers to Frame 23: 1. 250, VOLTS (10 meg Ω) 2. 1000 (highest)

3. DC-

536
Frame 25

1. Fill in the correct answers in the appropriate spaces for the meter scales shown below. The FUNCTION switch set at VOLTS (10 meg Ω), and POLARITY switch set at DC+. Be sure to indicate if value is volts or current and if it is AC or DC.



Range Switch Setting		Indication
a.	.5	_____
b.	2.5	_____
c.	10	_____
d.	50	_____
e.	250	_____
f.	500	_____
g.	1000	_____

2. For each of the following voltages, indicate on the blank, the range that should be used to obtain the most accurate readings.

Voltage		Range Switch Setting
a.	.15	_____
b.	1.5	_____
c.	15	_____
d.	150	_____
e.	750	_____

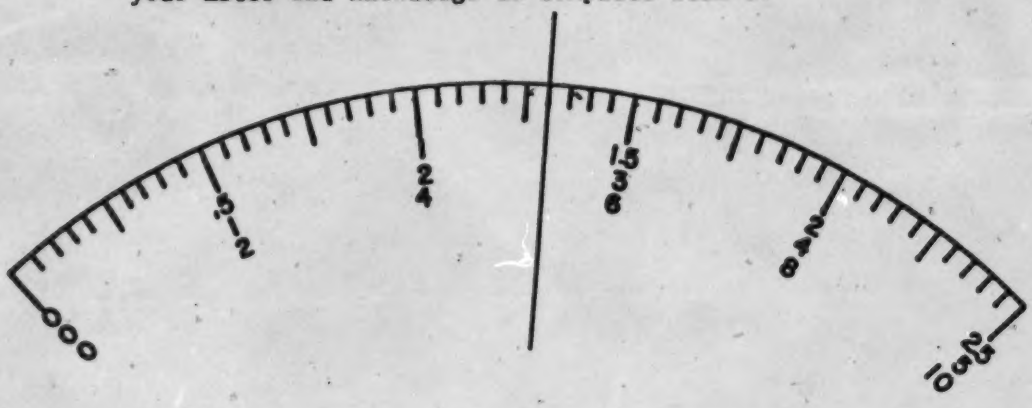
Answers to Frame 24: 1. 500 2. 50

The way that you read AC voltage is much the same as for reading DC volts. The only change is that you set the POLARITY switch to the AC position. You see that the POLARITY switch must be set to match the type of voltage or current that you will measure. Since AC stands for alternating current, the meter leads have no set polarity while measuring AC.

Place the correct answer in the spaces for the following exercise. For practice, set your meter up to measure the voltage value in problem number one.

1. To measure 240 volts AC, turn the POLARITY switch to _____, the RANGE switch to _____, the FUNCTION switch to _____ and take the readings from the 0 to _____ scale.

2. Use the meter scale below to complete items a and b. Use your meter and knowledge to complete item c.



a. Range switch at 50. Voltage indicated _____V AC.

b. Range switch at 250. Voltage indicated _____V AC.

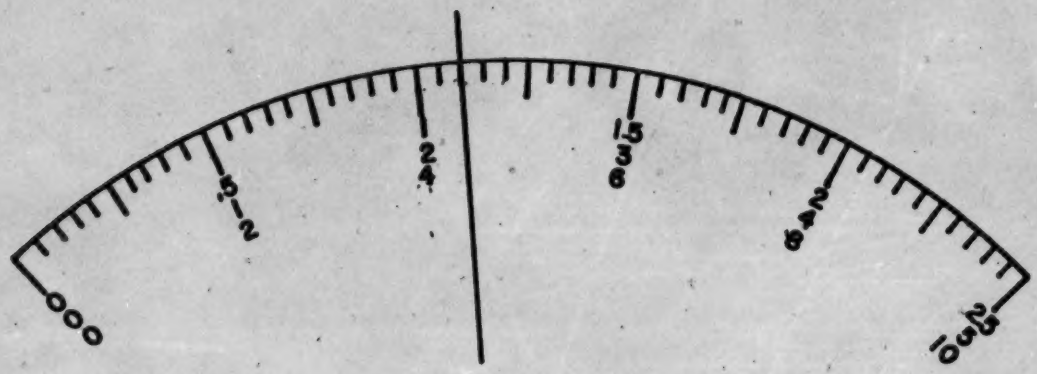
c. Range switch at _____ Voltage indicated 5.2V AC.

Answers to Frame 25: 1. a. .32 b. 1.6 c. 6.4 d. 32 e. 160 f. 320 g. 640 2. a. .5 b. 2.5 c. 50 d. 250 e. 1000

You use the same scales to read current as you used to read volts. To measure DC milliamperes (MA) set the POLARITY switch to the "DC+", set the FUNCTION switch to "MA/PULSE MA", and set the RANGE switch to the value that you wish to measure.

The PSM-37 can read up to 1000 MA which is the same as one ampere. To change MA to amps, move the decimal point three places to the left. Example: 1000 MA is 1 amp, 200 MA is .2 amp. To change amps to MA, move the decimal point three places to the right; 1 amp is 1000 MA, and .5 amp is 500 MA.

Note: The POLARITY switch position is determined by the polarity of the current applied to the RED test lead. Fill in the correct answer in the appropriate space for the following items.



1. FUNCTION switch set at AMPS, MA position.

   a. RANGE switch set at 1,000. Current indication is _____MA or _____amps.

   b. RANGE switch set at 500. Current indication is _____MA or _____amps.

   c. RANGE switch set at 250. Current indication is _____MA or _____amps.

   d. RANGE switch set at 10. Current indication is _____MA or _____amps.

Frame 27 (continued)

2. Set your meter up to measure 22 MA DC.

   a. The RANGE switch setting is _____.

   b. The POLARITY switch setting is _____.

   c. The FUNCTION switch setting is _____.

Answers to Frame 26:

1. AC, 250, VOLTS, 2.5

2. a. 26V AC b. 130V AC c. 10

545

When you use the PSM-37 as a milliameter, you will start on the highest range (1000) of the RANGE switch and work the switch down to the most accurate range. You should always push in on the PUSH TO OPEN and RESET button when you change the RANGE switch. This will cut down the chance of harm to the meter when measuring current. You should note that the most accurate reading on the AC & DC scale will be made when the needle moves as far right on the scale as it can, and still not go past the end of the scale.

Fill in the blanks below with the most accurate range switch position for each of the readings given. You may refer to your PSM-37 for a list of the ranges.

READINGS	RANGE	READINGS	RANGE
1. 40 MA	_____	4. 225 MA	_____
2. 400 MA	_____	5. 11 MA	_____
3. 4 MA	_____	6. 600 MA.	_____

Answers to Frame 27: 1. a. 440 MA, .44a b. 220 MA, .22a

c. 110 MA, .11a d. 4.4 MA, .0044a 2. a. 50 b. DC+ c. AMPS MA

The difference in the way that you set up the meter for measuring AC current rather than DC, is the way you set the POLARITY switch. To read AC, the POLARITY switch is set in the AC position.

Fill in the blanks with the correct response.

1. Using your PSM-37, set the controls up to measure 150 MA AC.

   a. FUNCTION switch position is _____.

   b. RANGE switch position is _____.

   c. POLARITY switch position is _____.

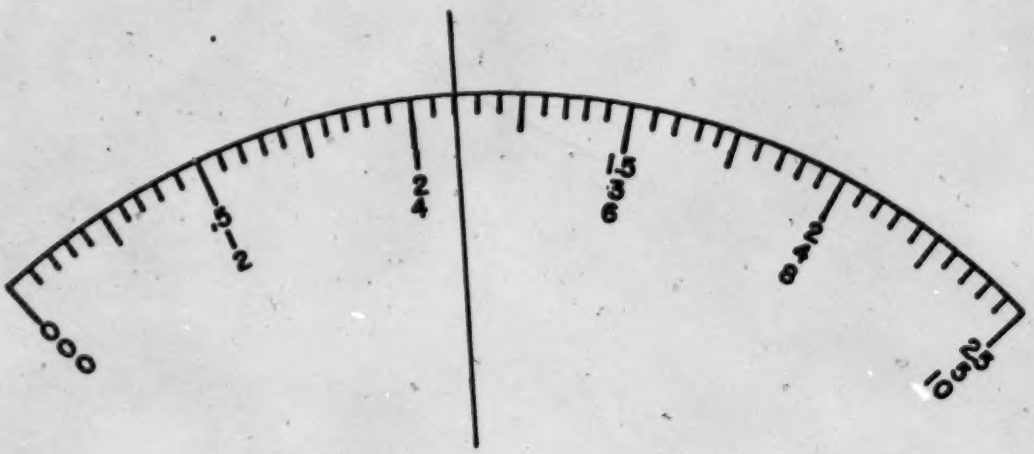
2. Using the meter scale below and your meter, fill in the blanks below with either the RANGE switch position or the indicated MA reading.

   a. Range switch at 1,000. Current indication is _____MA.

   b. Range switch at 500. Current indication is _____MA.

   c. Range switch at _____. Current indicated is 110 MA.

   d. Range switch at _____. Current indicated is 22 MA.



Answers to Frame 28: 1. 50 2. 500 3. 10 4. 250

5. 50 6. 1,000

Frame 30

This frame gives values that are to be measured. You will provide the positions of the POLARITY, FUNCTION, and RANGE switches, plus the scale and the group of digits that will be used to make the proper reading. Record this information on the blank spaces that are provided on the response sheet. You may use your meter as a reference.

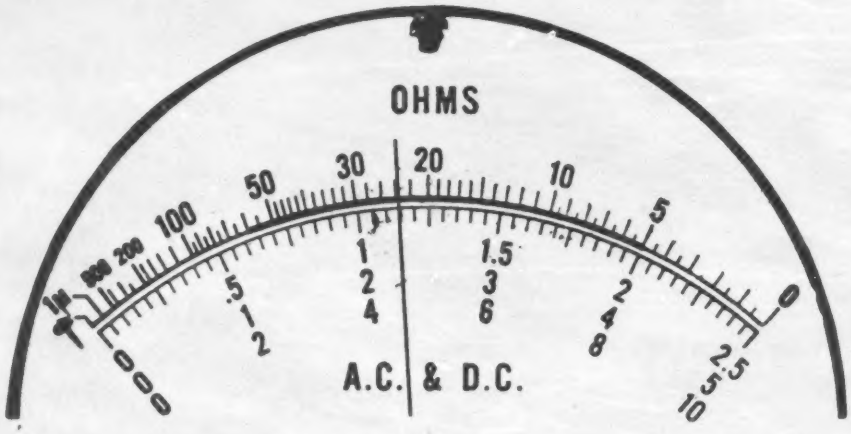
TO MEASURE	FUNCTION	RANGE	POLARITY	SCALE/GROUP
1. 230 Volts AC	VOLTS	250	AC	AC & DC/0-2.5
2. 1500 ohms				/
3. 225 Volts DC				/
4. 22 MA DC				/
5. 290 Volts AC				/
6. .43 Volts DC				/
7. 27,000 ohms				/
8. 17 ohms				/
9. 980 MA AC				/
10. 1.9 Volts AC				/
11. 9 MA DC				/
12. 6 ohms				/

Answers to Frame 29:

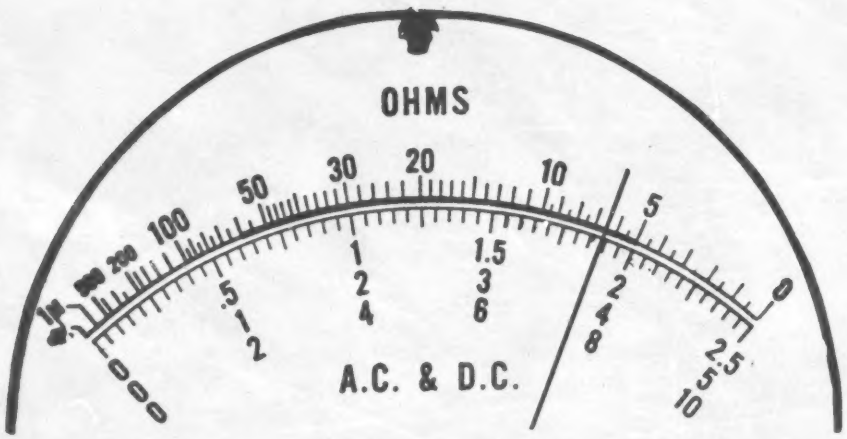
1. a. AMPS-MA b. 250 c. AC

2. a. 440 MA b. 220 MA c. 250 d. 50

In this frame you will be given one of the two meter faces shown and the position of the polarity, function, and range switches. You will be required to provide the proper reading of the meter.



Meter #1.



Meter #2.

These are the meter faces that you will use. The exercise that you are to fill out is on the next page.

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Frame 31 (continued)

Fill in the blanks with the proper meter readings. Be sure to use the meter referred to for each of the control settings. PLUS, indicate in your answer if the value is V DC, V AC, MA DC, MA AC, or Ω.

	METER NUMBER	FUNCTION Sw SETTING	RANGE Sw SETTING	POLARITY Sw SETTING	PROPER READING
1.	1	VOLTS	50	DC+	23V DC
2.	2	VOLTS	250	AC	
3.	2	OHMS-STD	R X 100	DC+	
4.	1	VOLTS	10	AC	
5.	2	VOLTS	.5	AC	
6.	1	OHMS-STD	R X 1K	DC+	
7.	1	AMPS-MA	50	AC	
8.	2	VOLTS	2.5	AC	
9.	1	OHMS-LP	R X 1	DC+	
10.	2	AMPS-MA	10	AC	
11.	2	OHMS-STD	R X 10	DC+	
12.	1	AMPS-MA	250	DC+	

Answers to Frame 30:

1.	VOLTS	250	AC	AC & DC/0-2.5
2.	OHMS-STD	R X 100	DC+	OHMS/0-∞
3.	VOLTS	250	DC+	AC & DC/0-2.5
4.	AMPS-MA	50	DC+	AC & DC/0-5
5.	VOLTS	500	AC	AC & DC/0-5
6.	VOLTS	.5	DC+	AC & DC/0-5
7.	OHMS-STD	R X 1K	DC+	OHMS/0-∞
8.	OHMS-LP	R X 1	DC+	OHMS/0-∞
9.	AMPS-MA	1000	AC	AC & DC/0-10
10.	VOLTS	2.5	AC	AC & DC/0-2.5
11.	AMPS-MA	10	DC+	AC & DC/0-10
12.	OHMS-LP	R X 1	DC+	OHMS/0-∞

To this point, all we have talked about is how to set the positions of the switches and how to read the PSM-37. We will now discuss how to use the meter to test for the value of volts, amps, and ohms in a circuit. A circuit is a path for current to flow. Before you can make the test, you must learn about how to determine the positive (+) and negative (-) side of the parts that are in a direct current (DC) circuit. You must also learn how to properly place the meter in the circuit to make a circuit test. In your next assignment, you will be going to the test lab and will have to test a circuit for volts, amps, and ohms.

NO RESPONSE REQUIRED.

Answers to Frame 31:

1.	23V DC	7.	23 MA AC
2.	190V AC	8.	1.9V AC
3.	650 Ω	9.	24 Ω
4.	4.6V AC	10.	7.4 MA AC
5.	.37V AC	11.	65 Ω
6.	24,000 Ω	12.	115 MA DC

If you have made any errors in the last two frames, review the frame(s) of this PT where this information was covered. If you still have difficulty, ask your instructor for assistance.

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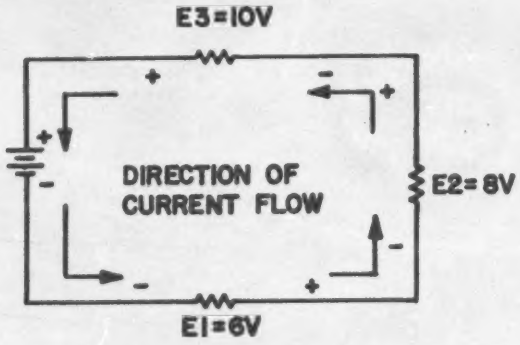
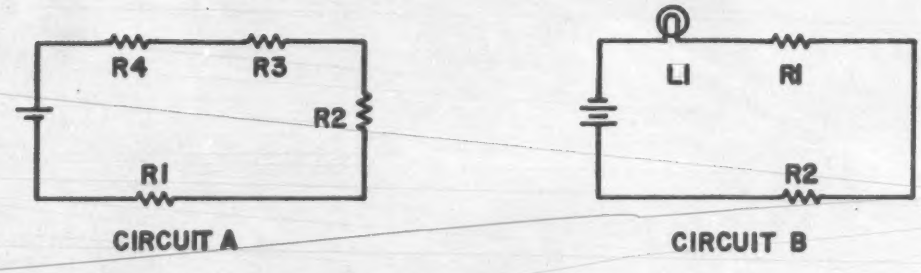
Frame 33

You have learned that the word direct means to go one way and current means the flow of electrons. Join the two words and you have direct current (DC). They mean a current that flows in one direction all the time. The flow will be from negative (-) to positive (+). Any time current flows in a circuit, a voltage will come across the components of the circuit. The polarity of this voltage drop can be found by the way that current flows through the component. In the circuit below, note that current is leaving the negative post of the battery, flowing through the circuit and returning to the positive post. As the current goes in a resistor, it will cause that end of the resistor to have a negative polarity. When it leaves a resistor it leaves that end with a positive polarity. This is true in all DC circuits.

Note: If the power source is not a battery, the negative side is sometimes marked "-" or is black; the positive side will have a "+" or painted red.



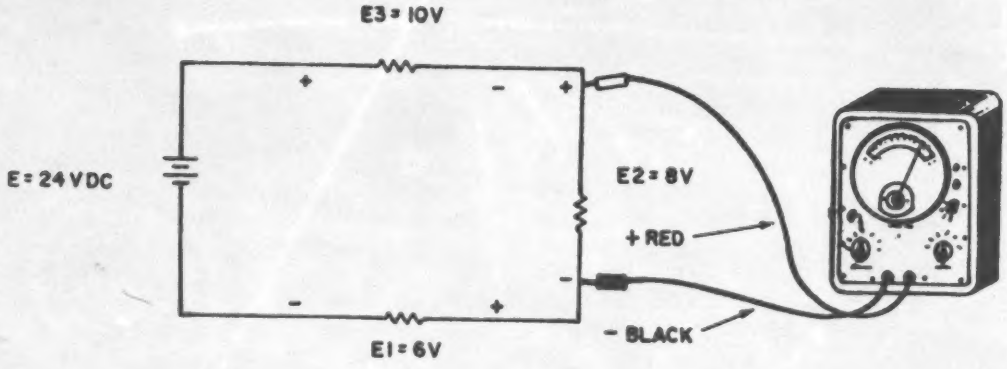
Place the right polarity to the components of the two circuits below. Also, point out with an arrow, the direction of current flow in the circuit.



Answer to Frame 32: No Response Required.

When you test for the voltage of a DC circuit you must watch the polarity of the voltage drop before you place the test leads in the circuit. Once you know the polarity, place the black lead of the voltmeter to negative and the red lead to positive. The meter must be connected across (in parallel with) the component being measured, as shown in the diagram below. If you place the meter or leads in some other manner, you will have a wrong reading. Plus, it could cause damage to the meter.

Note: Another thing that is important before you test for DC voltage, is that you should have your PSM-37 set up for the polarity value and the type of voltage that you will test.



In this manner, the voltmeter is connected in parallel.

Select the correct word and place it in the blank space to complete statements one, two, and three. For item four, fill in the blanks with the correct position of the switches.

1. When using the PSM-37 as a voltmeter, you would connect the meter in _____ (series/parallel) with the voltage to be measured.

2. If the meter is connected in series when making voltage checks, the readings will be _____ (accurate/inaccurate).

3. To measure the voltage E3 in the circuit above, the red lead will be placed on the _____ (right/left) of the resistor and the black lead on the _____ (other/same) end of the resistor.

4. Set your PSM-37 to measure the voltage E1 in the circuit above. The range switch position is _____, the polarity switch position is _____, and the function switch is set at _____.

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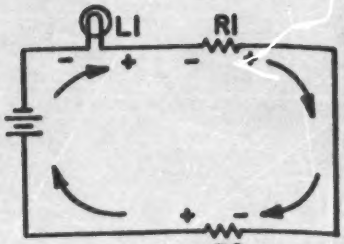
Frame 34 (continued)

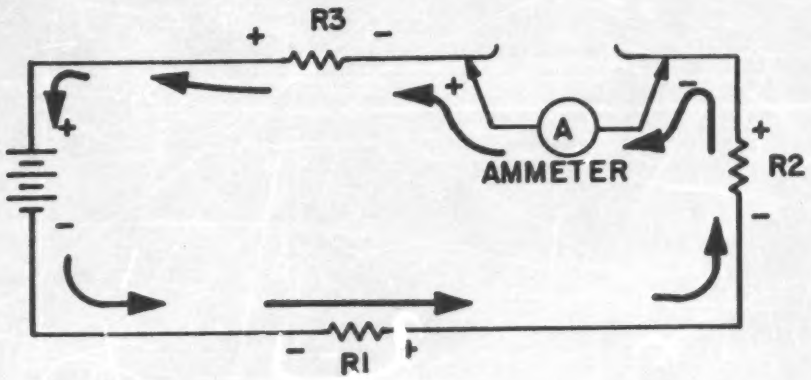
Answers to Frame 33:

CIRCUIT A



CIRCUIT B

To measure current flow, the meter must be connected in series in the circuit. When you connect it in series the same current that flows through the circuit is the same that flows through the PSM-37. Do not place an ammeter in parallel to measure current. If you do, the meter can be damaged or the reading you take will be inaccurate and low. The circuit below shows you an ammeter that is properly placed in a DC circuit.



Identify the true statement(s) by placing a T on the blank spaces provided.

_____1. The ammeter must be connected in series with the circuit component being checked.

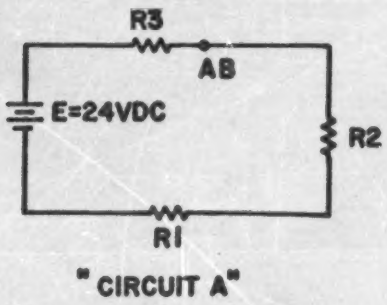
_____2. To accurately measure current, the same current must flow through both the meter and the circuit component being checked.

_____3. If the PSM-37 is connected in parallel to measure current, the readings would be inaccurate and low.

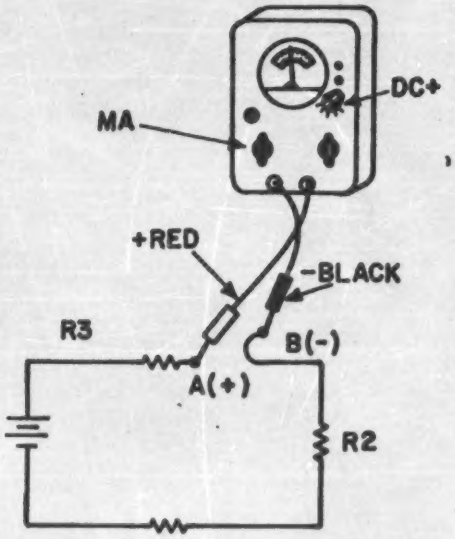
Answers to Frame 34:

1. parallel 2. inaccurate 3. left, other 4. 10, DC+, VOLTS - 10 Meg r

Study the two diagrams for a few moments before reading the rest of this frame.



"CIRCUIT A"



"CIRCUIT B"

To connect an ammeter in a circuit to test current flow, the circuit must be broken. Notice in circuit A that there is a point marked AB. In circuit B this point has been separated to form - - points "A" and "B". Since point "A" is connected to the plus (+) post of the battery through R3, point "A" is positive (+); point "B" is connected to the minus (-) post of the battery through R1 and R2 so it is negative (-). Remember, this circuit has DC volts applied. You must observe the polarity of the points to which the meter is connected.

The red test lead will be connected to point "A" and the black test lead connected to point "B". The circuit current now leaves the minus side of the battery, goes through R1, R2, in the black lead, through the meter, out the red lead, through R3 and back to the plus post of the battery.

Caution: Turn power "off" to the circuit when connecting and disconnecting an ammeter in and out of a circuit.

Frame 36 (continued)

Place the correct answer in the blank space provided, to complete the following statement(s).

1. Before the PSM-37 can be used to test circuit current, the circuit must be _____ and the meter placed in _____ with the circuit.

2. Set your PSM-37 up to measure 29 MA DC.

   The position of the switches are:

   a. Range switch _____.

   b. Function switch _____.

   c. Polarity switch _____.

Answers to Frame 35: T 1. T 2. T 3.

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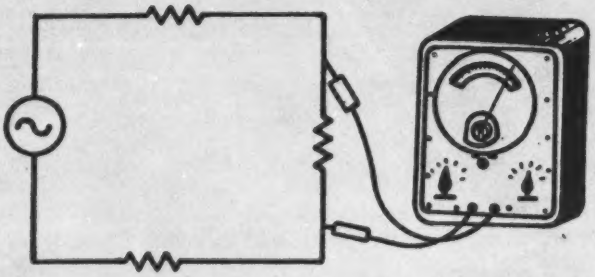
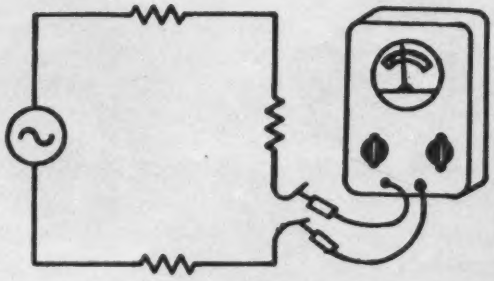
Frame 37

When you use the PSM-37 to measure the volts or amps in an AC circuit it is the same way as for DC circuits. The one difference is you do not need to observe polarity since AC means alternating current, a current that will first flow in one direction and then it will flow in the opposite direction.

To use the PSM-37 as an AC voltmeter, you must set the controls up properly; plus, you must place the meter in parallel with the voltage that you will test. For AC current measurements you must set the controls up properly, and you will connect the meter in series with the circuit.



Meter in PARALLEL TO measure AC voltage drop



Meter in SERIES to measure AC current flow

Place a checkmark (✓) beside the true statement(s).

_____1. You must observe polarity when measuring volts or amps in an AC circuit.

_____2. An ammeter is connected in series to measure voltage in an AC circuit.

Answers to Frame 36:

1. broken, series 2. a. 50 b. AMPS-MA c. DC+

There is an important safety precaution that you must follow when you use the ohmmeter functions of the PSM-37. Do not hook an ohmmeter to a live circuit (one that has power applied); be sure that no power is applied to the circuit. The parts in the meter need very little current to work. They are easy to damage if the meter were to be hooked to a "live" circuit. There is a small battery in the PSM-37 that gives us the current required to work the meter in the ohms function. Another important thing to remember is that the ohmmeter must be "zeroed" before you make your first ohms test. Think back; to zero the meter, first set the ohmmeter up for measuring resistance. Then, touch the two lead tips together. The needle should move to the right and zero over the "0" on the ohms scale. If it does not, turn the ohms ADJ knob until it does. If the needle does not move at all, press the "Push to Open and Reset" button. If it still will not zero, ask the instructor for help.

Place a "T" in the space provided beside each statement that is true.

_____1. The ohmmeter function of the PSM-37 requires current from the circuit being checked to operate.

_____2. The ohmmeter is "zeroed" before use to insure accuracy.

_____3. If the pointer cannot be adjusted to zero on the ohms scale, this means that the internal battery is weak.

Answer to Frame 37: _____1. _____2.

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Frame 39

After the ohms adj knob has been adjusted, the needle should stop at "0". This means that there is no resistance to current flow. Keep in mind that the meter lead tips must be touching each other or be in contact with a common conductor. If the needle stops to the left of "0", there is some opposition to the flow of current. If the needle only moves part of the way toward "0", there is resistance being measured. If the needle does not move at all, a great (infinite ∞) amount of opposition to the flow of current is present. We refer to each of these conditions by different terms. First, a "0" reading means that there is continuity (no resistance), in the circuit. A reading which will cause the needle to move, but to stop short of "0", means that there is resistance in the circuit. If the needle does not move at all, an open circuit is indicated, or the meter is at infinity "∞" and the resistance is either too large to be measured on that scale, or by that meter.

Place a "T" in the blank space beside each true statement.

_____1. Continuity refers to the amount of resistance in an open circuit.

_____2. A resistance that is too large to measure is referred to as infinity.

_____3. When the pointer is reading a value other than "0", this means some resistance is present in the component being checked.

Place the correct response in the space provided.

1. The component being checked with an ohmmeter must be _____ from the rest of the circuit.

2. The ohmmeter must NEVER be used to check the resistance of a circuit that has _____ on it.

3. The manner in which the ohmmeter is connected to the component being checked is similar to the way the voltmeter is connected; that is, in _____.

4. Set up your meter to measure 500 ohms of resistance. Place the position of your switches in the blanks below.

   a. Range _____

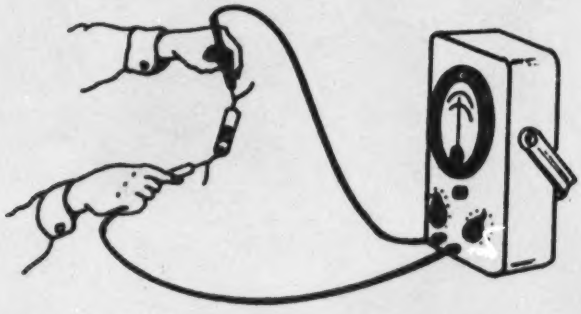
   b. Function _____

   c. Polarity _____

Answers to Frame 38: _____1. __T__2. __T__3.

Frame 40

The figure shows one test lead is placed to one side of the resistor. The other lead is placed to the other side of the resistor. When you make a resistance check on a component of a circuit, the component must be isolated (disconnected) from the rest of the circuit. This can be done in three ways: First, totally remove the resistor and test it out of the circuit; second, disconnect one end of the component to be tested from the circuit; third, is to take out the wire (conductor) leading up to one end of the component that you will test. In all three cases, the battery power from the meter will only have one path to flow through; that is, through the component being tested. If you do not isolate the part being checked, your ohms reading will be inaccurate.



Identify the true statement(s) by placing a "T" on the blank spaces provided on the response sheet.

_____1. The component being checked with an ohmmeter does not have to be isolated from the rest of the circuit.

_____2. The ohmmeter must never be used to check the resistance of a circuit that has power on it.

_____3. The manner in which the ohmmeter is connected to the component being checked is similar to the way the voltmeter is connected.

Answers to Frame 39:

____1. T 2. T 3.

1. isolated (or disconnected or removed) 2. power (or voltage)

3. parallel 4. a. R X 100 b. OHMS-STD c. DC+ (or-)

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Frame 41

If you check a high ohms resistor on a low R X range, the needle may not move off "∞" mark. Turn the range switch up range until the needle stops in the wide green area of the OHMS scale. Then take the reading times (X) the range switch position. This will give you the value of the resistor under test. With the range switch in a high R X position and meter leads hooked to a low ohms resistor, the needle may move to "0". In this case, turn the range switch down range. When the needle stops between the 5 and 60 of the ohms scale, take the reading. Multiply the reading times the range position to get the value of the resistor.

Place a "T" in the space provided beside each true statement.

_____1. With the ohmmeter on R X 100 and connected to a 10 ohm resistor, the needle will not move off "∞" mark.

_____2. With the PSM-37 set up on the R X 1 range and connected to a 2500 ohms resistor, the needle will move to 25 on the ohms scale.

Answers to Frame 40: _____1. __T__ 2. __T__ 3.

Frame 42

This frame summarizes the safety precautions that must be observed when using the PSM-37 to test circuits.

1. The PSM-37 should never be handled carelessly. Aside from being expensive, it is sensitive and delicate. Don't abuse it.

2. When measuring voltage and current, start your check with the range switch set on "1000". Then move it to a lower setting if necessary. Then turn it to a range higher than that applied to the circuit after making the check. This way the meter will be ready for the next check.

3. Never connect the ohmmeter to a circuit that has power on it.

4. When used as a voltmeter, connect it in "parallel" with the voltage drop being checked.

5. When measuring DC voltage and current, be sure to observe polarity when connecting the meter to the circuit. Note if the meter needle moves left on the scale, either reverse meter leads on the circuit or turn the polarity switch to the other DC position.

6. When used as an ammeter, connect it in "series" with the portion of the circuit being checked.

7. Before connecting the meter to a circuit, make sure it is set up for the values to be measured. (AC or DC volts and amps, or ohms)

8. Periodically check the strength of the internal battery. Accomplish this by zeroing the ohmmeter on each of the range switch settings. If it does not zero on all settings, the battery needs to be replaced.

9. Store the meter with the switches in the following positions: POLARITY switch "OFF," RANGE switch "1000," and FUNCTION switch VOLTS - 10 meg Ω. These positions give the meter some protection if the next person forgets to check the meter before placing it in a circuit.

Note: Place your meter controls in the positions listed above and return it to your instructor at this time. Do not proceed with this PT until you have done so.

NO RESPONSE REQUIRED.

Answer to Frame 41: _____1. _____2.

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Frame 43

Complete the following statements by entering the missing word(s) on the blank spaces provided.

1. When using the PSM-37 to measure a voltage of 34 volts DC, you will set the function selector to the (a) _____ position, the range switch to the (b) _____ position, and the polarity switch to the (c) _____ position. The reading will be taken from the 0 to (d) _____ scale.

2. When using the PSM-37 to measure .008 amps DC, you will move the function switch to (a) _____, polarity switch to (b) _____, and range switch to (c) _____. The reading will be taken from the 0 to (d) _____ scale.

3. When measuring 210 volts AC, you will move the function switch to the (a) _____ position, polarity switch to (b) _____, and range switch to (c) _____. Your readings will be taken from the 0 to (d) _____ scale.

4. When using the PSM-37 as an ohmmeter you will take the readings from the (a) _____ (color) scale. The function switch must be set to the (b) _____ position when making resistance checks. Now assume you are checking a resistor; you have the range switch set to R X 1K and the pointer stops at 21 on the OHMS scale. The reading of 21 is multiplied by (c) _____ and the value of the resistor is (d) _____ ohms.

Place a "T" in the blank space beside each true statement.

_____5. The ohmmeter readings will be most accurate when the readings are taken when the pointer is stopped in the wide green area of the ohms scale.

_____6. When measuring voltage, the meter must be connected in series with the component being checked.

_____7. If the ohmmeter is not "zeroed" properly, you will get inaccurate readings.

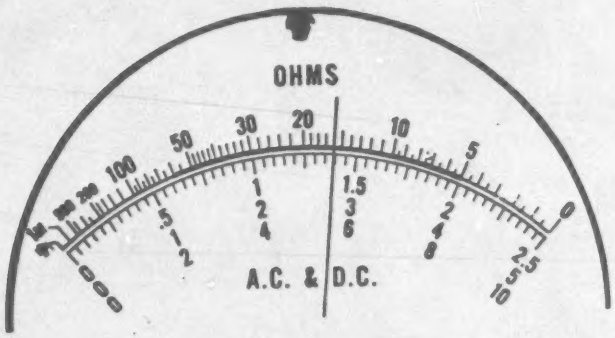
_____8. A DC ammeter must be connected in series with the component being checked and you must observe polarity when connecting the leads.

Match the items in the right-hand column to their correct statement in the left-hand column. Enter your letter answers in the space provided.

____9.	An indication of zero ohms.	A.	Black test lead
____10.	Determine whether the meter measures ohms, volts or milliamps.	B.	Press to Open and Reset Button
____11.	Is always connected to the positive point of a DC circuit.	C.	Continuity
____12.	An unmeasurably large resistance.	D.	PSM-37
____13.	Provides current in the ohms function only.	E.	Red test lead
____14.	Used to make the pointer of the ohmmeter read exactly "0".	F.	Range switch
____15.	Used to measure AC and DC current and voltage, plus resistance.	G.	External switch
____16.	Is always connected to the negative point of the circuit.	H.	Function switch
____17.	Determines the meters maximum voltages and current or multiplier for resistance readings.	I.	Internal battery
____18.	Protects the meter from overload and can be used to break the input circuit to the meter.	J.	Infinity
		K.	Ohms Adj knob
		L.	Red indicator

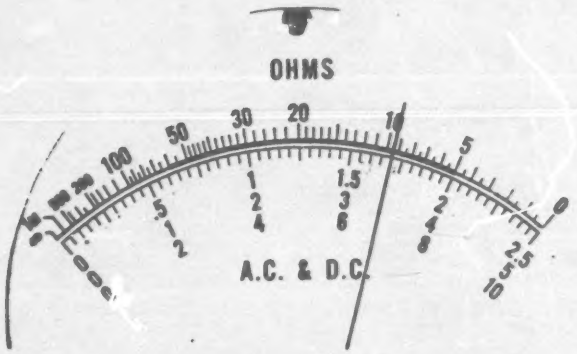
Frame 43 (continued)

19. The function switch is set on VOLTS and the polarity switch is on AC. Use the meter face below to obtain the readings for the range switch positions given in the chart below the meter face.



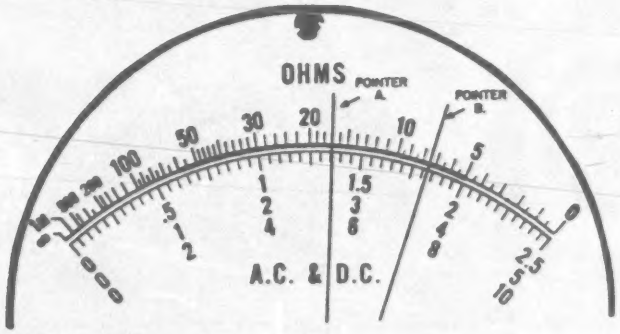
RANGE SW. →	.5	10	50	250
READINGS →				

20. The function switch is set to AMPS-MA and the polarity switch is set to DC+. Use the meter face below to obtain the readings for the range switch position given in the chart below the meter face.



RANGE SW. →	2.5	10	500	1000
READINGS →				

21. The function switch is set to ohms and the polarity switch to DC+. Use the meter face below to obtain the readings for the range switch positions given in the chart below the meter face. Enter pointer A readings in line one and pointer B in line two.

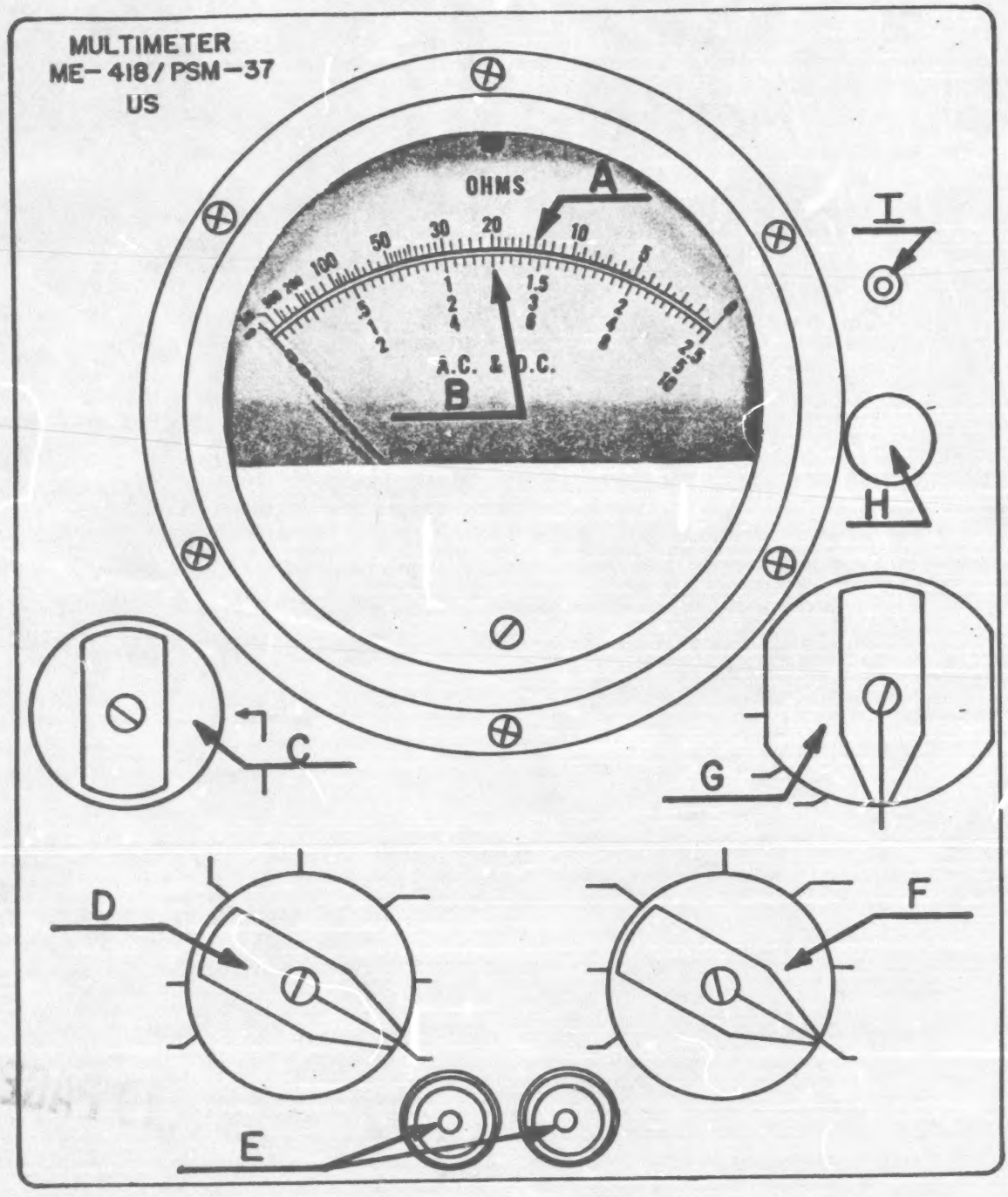


RANGE SW. ⟶	RX10	RX1K	RX100K
POINTER "A"			
POINTER "B"			

22. Using the illustration of the complete PSM-37 meter on the next page, match the names of the controls and scales in Column A with the letter that corresponds to that item from the illustration. Place your letter answers in the space provided in Column B.

Column A		Column B
a.	Overload	_____
b.	Polarity switch	_____
c.	Function switch	_____
d.	Ohms - Adj	_____
e.	Ohms (Green)	_____
f.	AC & DC	_____
g.	Push to Open and Reset	_____
h.	Test Jacks	_____
i.	Range switch	_____

22. Continued. This illustration is to be used in conjunction with item 22, matching exercise of meter controls and scales.



Answers to Frame 43:

1. (A) Volts
   (B) 50
   (C) DC+
   (D) 5

2. (A) AMPS-MA
   (B) DC+
   (C) 10
   (D) 10

3. (A) Volts
   (B) AC
   (C) 250
   (D) 2.5

4. (A) Green
   (B) Ohms
   (C) 1000
   (D) 21,000

5. T
6. F
7. T
8. T
9. C
10. H
11. E
12. J
13. I
14. K
15. D
16. A
17. F
18. B

19.

.5	10	50	250
28VAC	5.6VAC	28 VDC	140VAC

20.

2.5	10	500	1000
1.7MA DC	6.8MA DC	340MA DC	680 MA DC

21.

RX10	RX1K	RX10OK
170	17,000	1,700,000
75	7500	750,000

564

Answers to Frame 43 (continued):

22. a. I
    b. G
    c. D
    d. C
    e. A
    f. B
    g. H
    h. E
    i. F

If you missed any of these items, turn to the part(s) of this PT which covered the item tested. If you still do not fully understand that item, ask your instructor for assistance.

76-40541

Technical Training

Aircraft Environmental Systems Mechanic

AN/PSM-37 MULTIMETER PERFORMANCE

28 April 1980

CHANUTE TECHNICAL TRAINING CENTER (ATC)
3370 Technical Training Group
Chanute Air Force Base, Illinois

Designed for ATC Course Use.

Do Not Use on the Job.

566

Environmental Pneudraulics Branch
Chanute AFB, Illinois

3ABR42331-WB-112

PSM-37 MULTIMETER PERFORMANCE

OBJECTIVES

Using a multimeter, voltage and resistive console, measure and record electrical and resistive values within + or - 10% of the actual values.

EQUIPMENT

	Basis of Issue
AN/PSM-37	1/student
Multimeter Trainer, P/N 18-70-4104	1/student

PROCEDURE

1. REMOVE ALL JEWELRY.

2. Proceed to the lab where the trainer is located.

3. Follow all the projects according to the instructions as stated.

4. Insure the instructor has connected power to the trainer.

5. When you leave your trainer for scheduled or unscheduled breaks, insure the following has been done before you go.

   a. Place your power switch to the OFF position.

   b. Secure your meter at this time.

      (1) Insure the controls on the meter are properly set for storage.

      (2) Leave the test leads attached to the meter.

      (3) Wrap the leads around the instrument.

      (4) Place the meter on the locker shelf.

   c. When you return from the break, take the same meter and go back to work.

Supersedes 3ABR42331-WB-108, 18 October 1977.
OPR: 3370 TCHTG
DISTRIBUTION: X
3370 TCHTG/TTGU-P - 300; TTVSA - 1

Note: In the first projects, you will be doing practice problems on taking voltage and resistance readings. At the end of the practice problems a progress check will be made on which you will be given an S or U. If you have any questions after completing the practice problems, please ask your instructor before starting the progress check.

Project 1

INSTRUCTIONS

With the multimeter function switch set for voltage and the polarity switch set for DC +, read and record the voltage for each checkpoint listed, in the spaces provided.

Note: If at any time during the following projects and progress check, your meter needle floats and/or fluctuates, see your instructor for advice, if needed.

Step 1. Shown in figure 1 is an example of how your meter leads should be connected to the circuits being checked. Note that the black meter lead is connected to the point marked ⏚. The red lead is connected at each point being checked. In the figure also note that the red lead is connected to Point "A" of the DC voltage panel. To take further readings, simply move the red lead to the points to be checked (a-d). Go NO FURTHER than D.

Note: Be sure to set the multimeter to the highest range when checking for unknown voltages. Then work (turn) the range selector switch down.

Make sure you complete the following steps for each voltage problem.

1. Set the range switch to 1000. Connect red lead to checkpoint.

2. Use the correct scale on the meter and determine if the voltage is below 500V.

3. If it is, turn the range selector to 500. If not, leave the range switch on 1000 and take a reading.

4. If you turned it down to the 500 range, determine if the voltage is less than 250V. If it is, turn the range switch down. If not, take a reading.

5. Proceed in this manner for each range until you find the lowest possible setting. Make sure you do not turn the range switch to a setting that is lower than the amount of voltage you are measuring.

Note: If you do not disconnect the test leads from the live circuit when changing the "range" switch you must push in on the "push to open and reset" button during range switch movement.

If the meter pegs out to the extreme right, immediately remove your red lead and turn the range to a higher setting.

Step 2. Locate the "POWER PANEL" and turn the "ON and OFF" switch to the "ON" position. The red power light should glow when the trainer power is on. If the light fails to come on, notify the instructor.

Step 3. Using the multimeter, set your meter for DC voltage, then read and record the voltages for points "A" through "D" only. Be sure that you have the black meter lead inserted into the ground

⊣|| checkpoint.

PRACTICE PROBLEMS

DC CHECKPOINTS	VOLTAGE READINGS
A.	_____volts
B.	_____volts
C.	_____volts
D.	_____volts

Upon completion of this project, see your instructor if you have any questions, also have the instructor check your answers for accuracy.

Have the instructor initial below before you progress.

Instructor's Initials _____

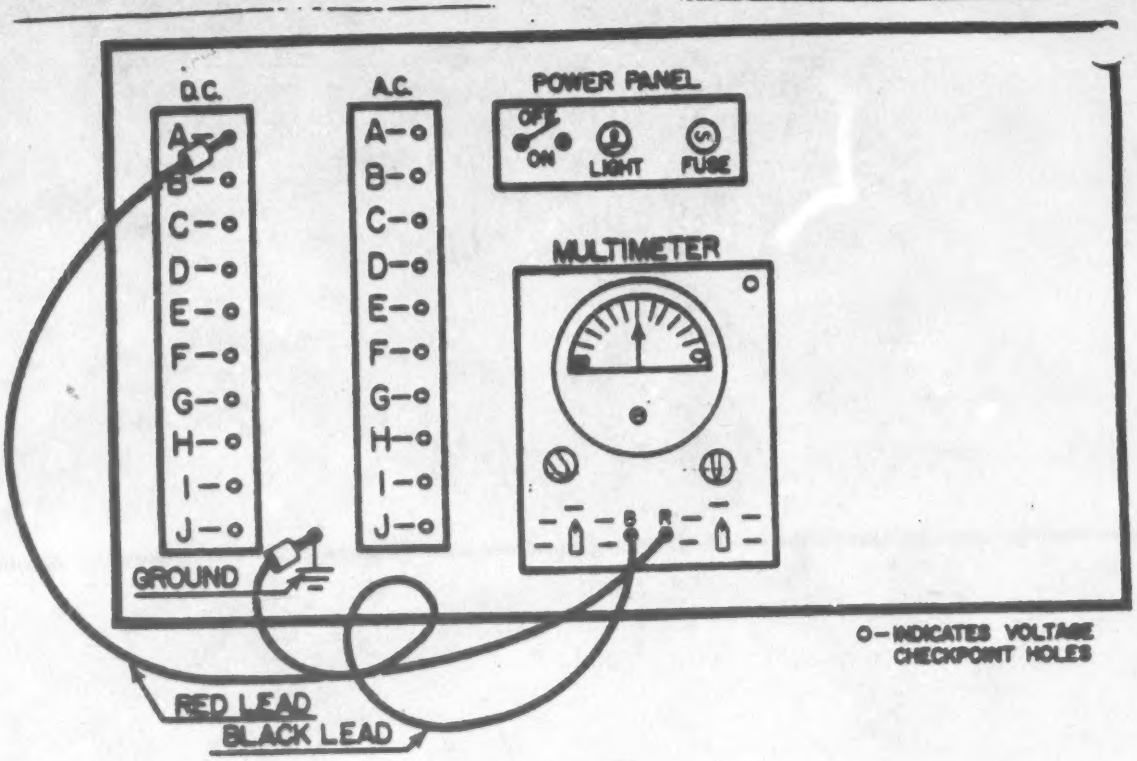


Figure 1.

Project 2

INSTRUCTIONS

With the multimeter function switch set for voltage and the polarity switch set for AC, read and record the voltage for each checkpoint listed, in the spaces provided.

Note: If at any time during the following projects and progress check, your meter needle floats and/or fluctuates, see your instructor for advice, if needed.

Step 1. Connect the multimeter leads the same as you did when taking the DC voltage readings on the DC panel. Remember, set your meter high and work down for unknown voltages. Be sure that you have the black meter lead inserted into the ground checkpoint.

Step 2. Read and record the AC voltages for checkpoints "A" through "D".

570 PRACTICE PROBLEMS

AC CHECKPOINTS	VOLTAGE READINGS
A.	_____volts
B.	_____volts
C.	_____volts
D.	_____volts

Upon completion of this project, see your instructor if you have any questions, also have the instructor check your answers for accuracy.

Have the instructor initial below before you progress.

Instructor's Initials _____

Project 3

INSTRUCTIONS

Note: Turn the trainer power switch "OFF".

Using Ohms portion of your multimeter, read and record the resistance for the resistors listed. The resistors are located on the right side of the meter. Place the polarity switch to + DC and the function switch to ohms. To take readings just place the black lead at one end of the resistor and the red lead at the other end of the resistor. When using OHMS only, there is no + or - end of a resistor.

PRACTICE PROBLEMS

	RESISTOR CHECKPOINTS	RESISTANCE READINGS
1.	1 to 2	_____ohms
2.	3 to 4	_____ohms
3.	5 to 6	_____ohms
4.	7 to 8	_____ohms
5.	9 to 10	_____ohms
6.	11 to 12	_____ohms
7.	13 to 14	_____ohms
8.	15 to 16	_____ohms
9.	17 to 18	_____ohms
10.	19 to 20	_____ohms

If you have any questions on how to use the ohms portions of your multimeter, please be sure to ask the instructor at this time. If you have no questions, continue on with the remainder of this project.

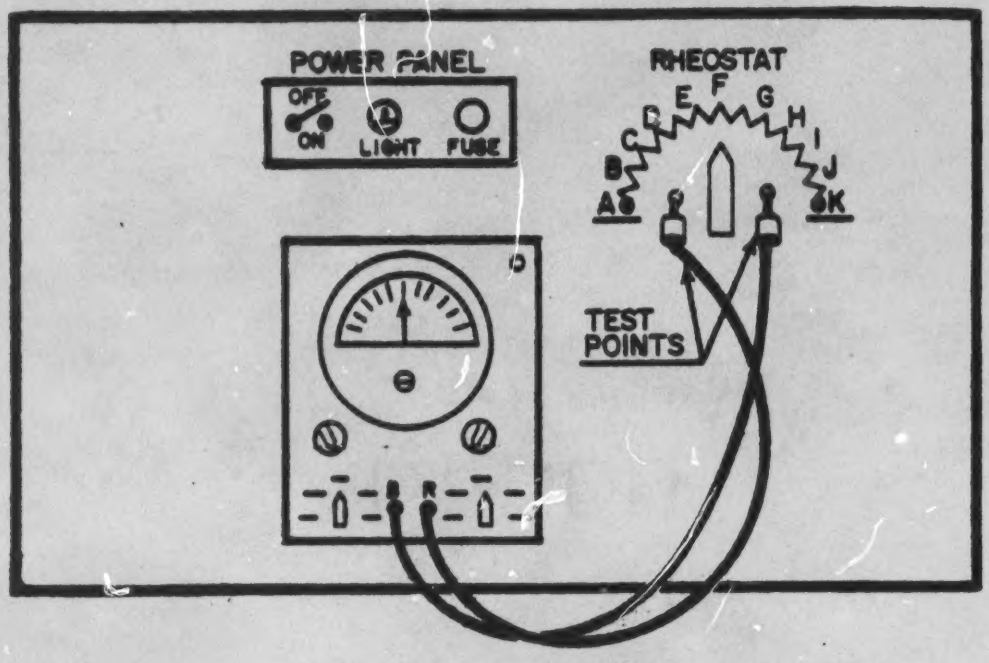


Figure 2.

Position the rheostat on the trainer on the right side of the power panel (note in figure 2, A thru K), to the checkpoints indicated below. Read and record the resistance values in the spaces provided.

PRACTICE PROBLEMS

RHEOSTAT CHECKPOINTS	RESISTANCE READINGS
B.	_____ ohms
E.	_____ ohms
G.	_____ ohms
I.	_____ ohms
K.	_____ ohms
C.	_____ ohms

Upon completion of this project, see your instructor if you have any questions, also have the instructor check your answers for accuracy.

Have the instructor initial below before you progress.

Instructor's Initials _____

Project 4

INSTRUCTIONS

The trainer has six (6) different test circuits. Using the first circuit you will learn to identify whether a circuit is good, shorted or open.

Note: Insure the power is turned OFF when using the ohmmeter.

Step 1. Connect the ohms portion of the multimeter across the top test circuit. This circuit is identified by checkpoints A to B (top circuit on the test circuit panel). These test circuits are located just to the left of the POWER PANEL.

Step 2. Move the test switch in circuit #1 to the UP position. Note that the multimeter indicates a "0" (zero) ohms reading. This reading indicates one or two things:

1. IF the circuit being checked DOES NOT contain a resistor but is only a straight length of wire, the meter indicates that the circuit is GOOD.

Note: A continuous run of wire must indicate continuity "0" (zero) ohms, IF NOT then it is bad.

2. IF the circuit being tested DOES contain a resistor, then the meter reading of zero ohms would indicate that the circuit in question is SHORTED.

Note: Simply a resistor must indicate a certain resistance value. This value should be greater than zero ohms and less than (∞) infinity.

Step 3. Move the test switch to the DOWN position and again note the meter reading. The meter should indicate infinity (∞). Remember -

1. When reading a straight, continuous piece of wire, the meter should read zero ohms.

2. When reading a resistor in a wire, the meter should indicate a resistive value.

Note: IF the meter reads infinity, this indicates that the circuit is OPEN (broken). If it is OPEN, you no longer have a completed path through the circuit for electron flow.

Step 4. Move the test switch back and forth until you are sure you can properly identify a shorted or opened circuit. Keep in mind that you are using the switch as a resistor.

Step 5. If you have any questions about OPENS, SHORTS, or a GOOD circuit, ask your instructor at this time. If you do not have any questions, continue and check the remaining five test circuits and determine if each circuit is GOOD, OPEN or SHORTED, and then write either GOOD, OPEN, or SHORTED in the blanks below.

PRACTICE PROBLEMS

CIRCUIT NUMBER	CHECKPOINTS	INDICATION
2	C to D	_____
3	E to F	_____
4	G to H	_____
4	H to I	_____
5	J to K	_____

Upon completion of this project, see your instructor if you have any questions, also have the instructor check your answers for accuracy.

Have the instructor initial below before you progress.

Instructor's Initials _____

This completes the multimeter practice projects. Insure that the trainer power switch is in the OFF position.

Turn this workbook in to your instructor for your progress check assignment. _

PROGRESS CHECK INSTRUCTIONS

This progress check will require you to measure and record electrical and resistive values within + or - 10% of the actual values. This should be accomplished in much the same manner as the practice problems. The instructor will initial your work after you have satisfactorily completed the progress check.

PROGRESS CHECK

_____ _____
Student Name Date

Instructor's Initials _____

Take the following resistance readings:

21 to 22 _____ ohms

23 to 24 _____ ohms

25 to 26 _____ ohms

27 to 28 _____ ohms

29 to 30 _____ ohms

31 to 32 _____ ohms

33 to 34 _____ ohms

35 to 36 _____ ohms

37 to 38 _____ ohms

39 to 40 _____ ohms

Rheostat

A. _____ ohms

C. _____ ohms

D. _____ ohms

F. _____ ohms

H. _____ ohms

J. _____ ohms

Take the following voltage readings:

DC	AC
E. _____ volts	E. _____ volts
F. _____ volts	F. _____ volts
G. _____ volts	G. _____ volts
H. _____ volts	H. _____ volts
I. _____ volts	I. _____ volts
J. _____ volts	J. _____ volts

Upon completion of this progress check, see your instructor to have your answers checked for accuracy.

Instructor's Initials _____ Progress Check Grade _____

PROGRAMMED TEXT
3ABR42331-PT-114

Technical Training

Aircraft Environmental Systems Mechanic

KIRCHHOFF'S CURRENT LAW

1 September 1977

3350 TECHNICAL TRAINING WING
3370 Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE
DO NOT USE ON THE JOB

FOREWORD

This programmed text was prepared for use in Course 3ABR42331, Aircraft Environmental Mechanic. The material contained herein has been validated with students from the subject course. Ninety percent of the students achieved the objective as stated. Average time to complete this text was 2 hours.

OBJECTIVE

Using Kirchhoff's current law, solve for unknown values in basic electrical circuits. A minimum of eight out of the ten unknown must be correct.

INSTRUCTIONS

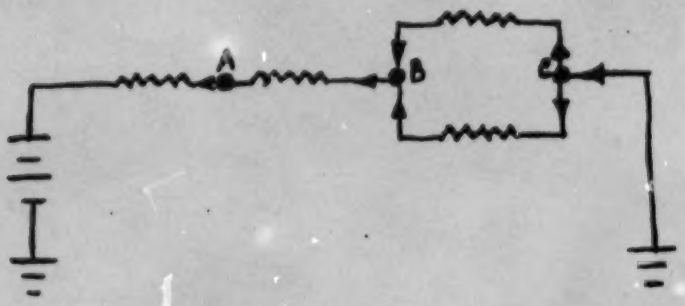
This PT presents information in small steps called "frames." Carefully study the written material and/or diagram in each frame until you are satisfied that you understand its contents. Each frame requires you to respond to the information in some way. For example, you may be required to solve for unknowns in circuits. Specific instructions are provided in each frame. After you have made your response on the response sheet, compare your answers with the answers given on the top of the next page. If you are correct, go on to the next frame. If you are incorrect, study the frame again and correct your mistakes before continuing. Read carefully, select the correct answers and DO NOT HURRY. DO NOT MARK IN THE TEXT!

OPR: 3370 TTG
DISTRIBUTION: X
3370 TTGIC - 200; TTVSR - 1

Frame 1

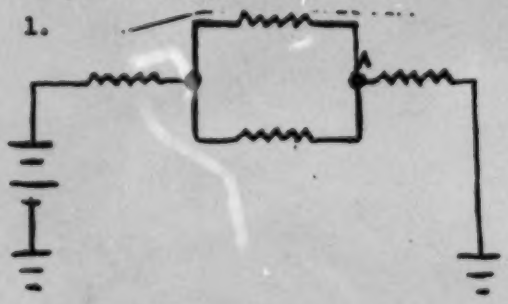
Kirchhoff's current law is stated as follows: The sum of the currents that flow into any junction of conductors is equal to the sum of the currents that flow away from that junction. In order to apply this law, you must understand what we mean by a junction of conductors. A junction is the point where two or more conductors are joined together. In the figure shown, we have identified junctions at points A, B, and C.

There is one path for current to flow into junction C and two paths for current to flow out of junction C. The arrows are indicating the direction of current flow in the circuit. There are two paths for current to flow into B and one path for current to flow out of B. There is one path for current to flow into junction A and one path for current to leave A.



For each of the junctions lettered in the circuits below, indicate how many paths are leading into the junction and how many are leaving. Remember, current flows from a negative potential to a positive potential. The short line of the battery symbol represents the negative terminal. Put your answer on the appropriate blank on the response sheet.

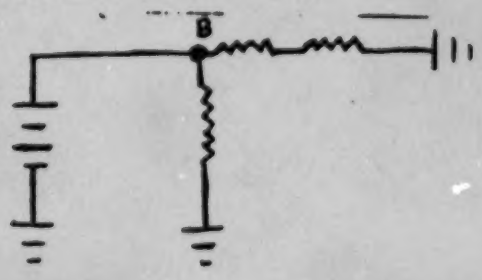
1.



a. How many paths leading into A? ____

b. How many paths leaving A? ____

2.

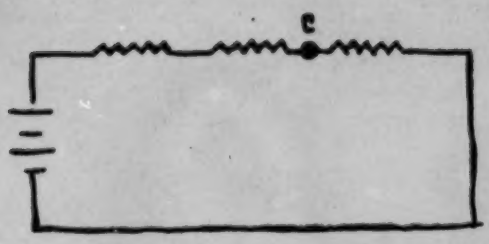


a. How many paths leading into B? ____

b. How many paths leaving B? ____

Frame 1 (Continued)

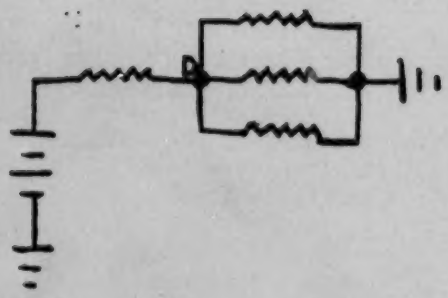
3.



a. How many paths leading into C? _____

b. How many paths leaving C? _____

4.



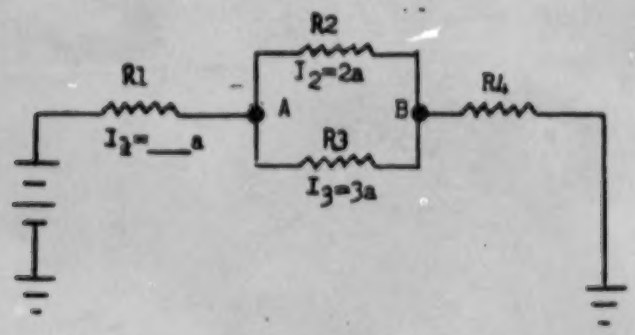
a. How many paths leading into D? _____

b. How many paths leaving D? _____

Answers to Frame 1: 1a. 1 b. 2 | 2a. 2 b. 1 | 3a. 1 b. 1 | 4a. 3 b. 1

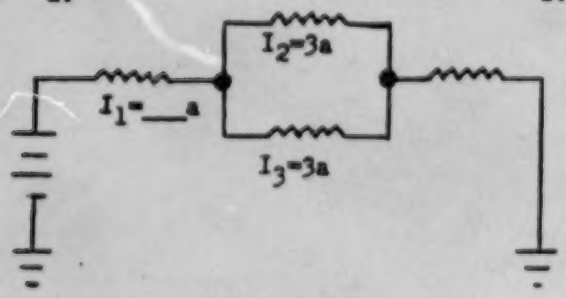
Frame 2

Now that you understand how to determine how many paths are leading into a junction and how many are leaving, you are ready to learn how to apply Kirchhoff's current law in solving for unknown currents in a circuit. First, we'll restate the law: The sum of the currents flowing into a junction of conductors is equal to the sum of the currents flowing away from that junction. To demonstrate how to apply this law we will use the circuit shown below. In the circuit below we need to find the amount of current flowing through R1. Applying Kirchhoff's current law to junction A, we have the sum of the currents flowing into A, $I_2 + I_3 =$ 5a. Thus, we must have 5a leaving A. Therefore, $I_1 = 5a$.

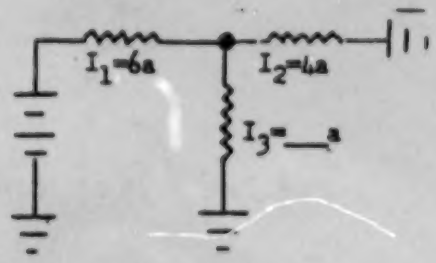


Determine the unknown current in each of the circuits below. Put your answers on the appropriate blank on the response sheet.

1.



2.

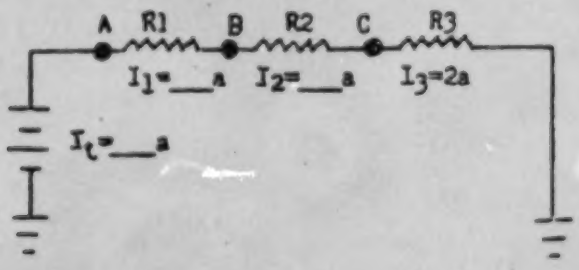


Answers to Frame 2: 1. 6a 2. 2a

Frame 3

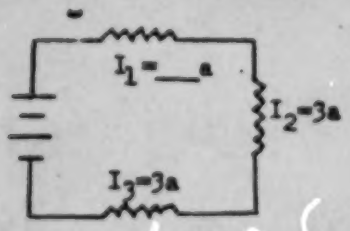
In this frame you will see that Kirchhoff's current law is valid in an actual circuit.

Since there is only one path for current flow, it must be the same at any point in the circuit. Let's see why. In the circuit below we want to find the values of I_t, I_1, and I_2. There are 2 amps flowing into junction C. Using Kirchhoff's current law we have 2 amps leaving junction C. Since there is only one path leaving junction C, the current through R_2, I_2, must also be 2 amps. Thus, we have 2 amps flowing into junction B. Since there is only one path leaving B, I_1 = 2a. Since there are 2 amps flowing into junction A and there is only one path leaving junction A, I_t must also be 2 amps. Fill in 2a for I_t, I_1, and I_2 in the circuit below.

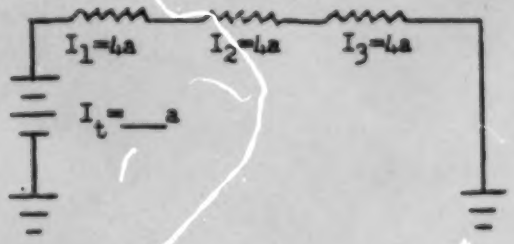


Using Kirchhoff's current law, solve for the unknown currents in each of the following circuits. Put your answers on the appropriate blank on the response sheet.

1.



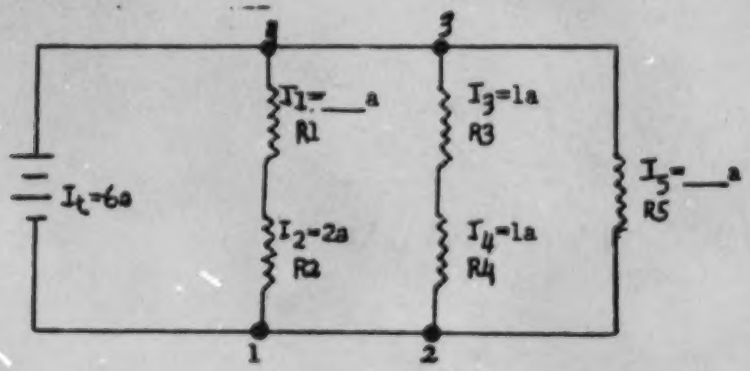
2.



Answers to Frame 3: 1. 3a 2. 4a

Frame 4

In the last frames you saw that Kirchhoff's current law is valid in an actual circuit. The remainder of this lesson is going to give you practice applying Kirchhoff's current law to various circuits. First, we'll give one more example problem that is worked out step-by-step. Since I_t = 6a in the circuit below, there are 6 amps flowing into junction 1. Applying Kirchhoff's current law we have 6 amps leaving junction 1. Since there are 2 amps flowing up through R_2, there must be 4 amps flowing into junction 2. Thus, there must be 4 amps leaving junction 2. Since there is 1 amp flowing up through R_4, there must be 3 amps flowing into R_5. Thus, I_5 = 3a. Fill in 3a for I_5. Next we want to find the value of I_1. Since there are 2 amps leaving R_2, there must be 2 amps flowing into R_1. Thus, I_1 = 2a. Fill in 2a for I_1.

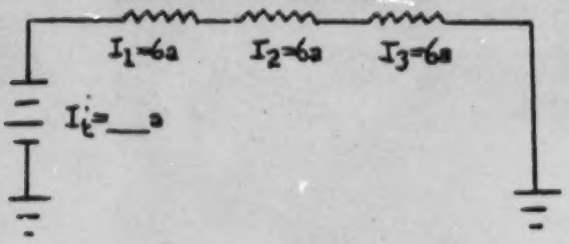


NO FURTHER RESPONSE REQUIRED, PROCEED TO THE NEXT FRAME.

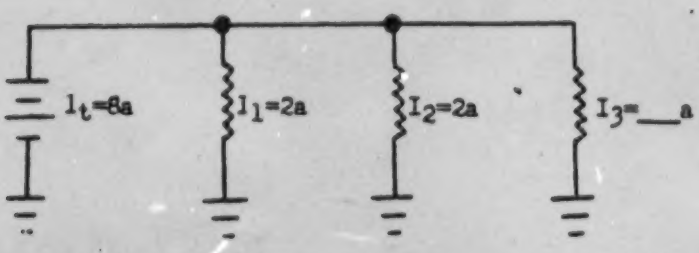
Frame 5

Using Kirchhoff's current law, analyze the circuits below to determine the unknown current in each circuit. Put your answers on the appropriate blank on the response sheet.

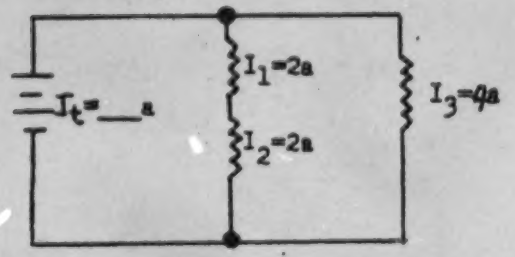
1.



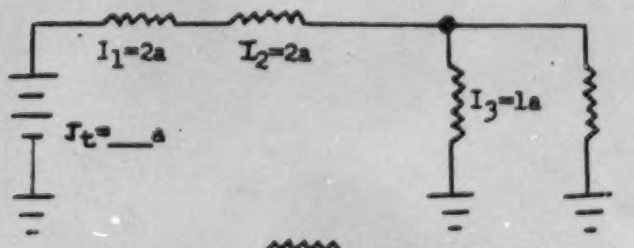
2.



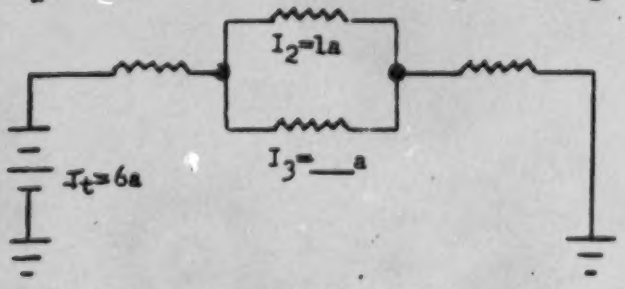
3.



4.



5.

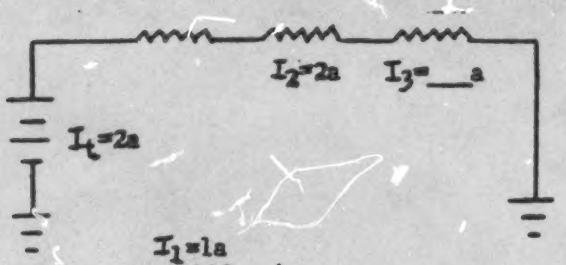


Answers to Frame 5: 1. 6a 2. 4a 3. 6a 4. 2a 5. 5a

Frame 6

Using Kirchhoff's current law, analyze the circuits below to determine the unknown current in each circuit. Put your answers on the appropriate blank on the response sheet.

1.



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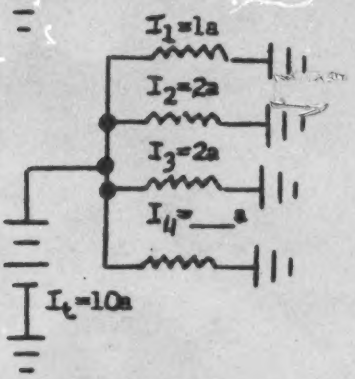
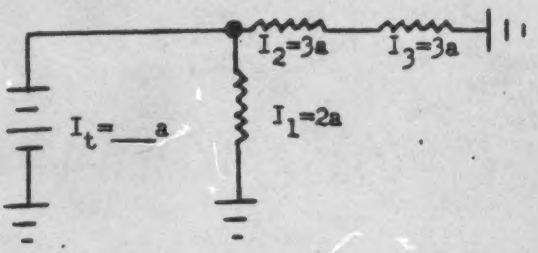
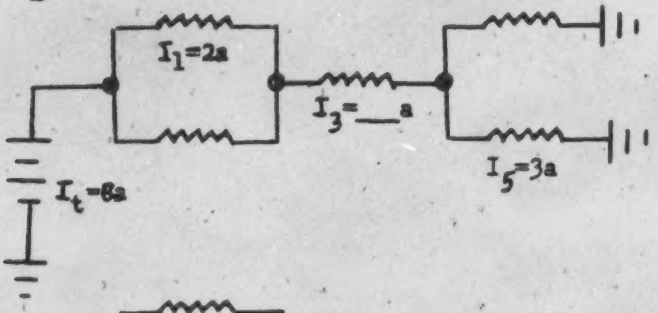


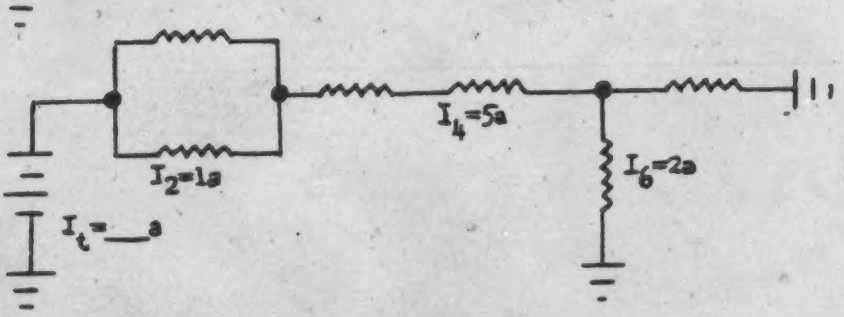
3.



4.



5.



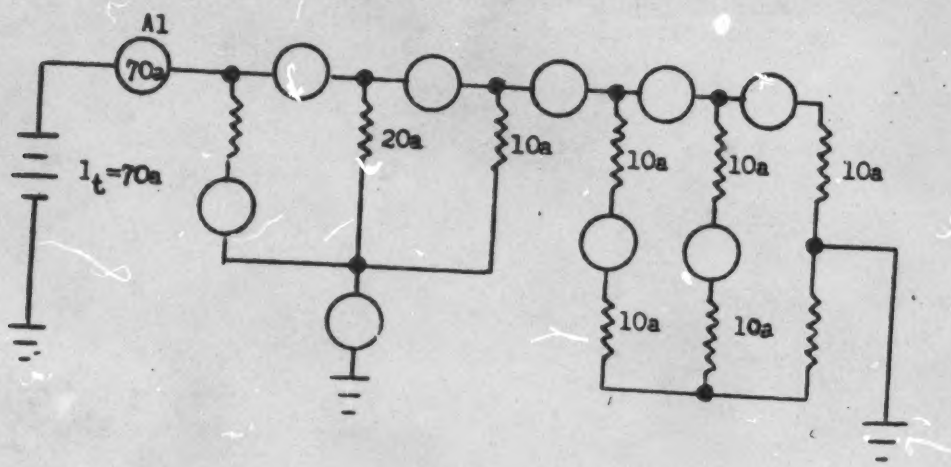
584

Answers to Frame 6: 1. 2a 2. 5a 3. 5a 4. 8a 5. 5a

Frame 7

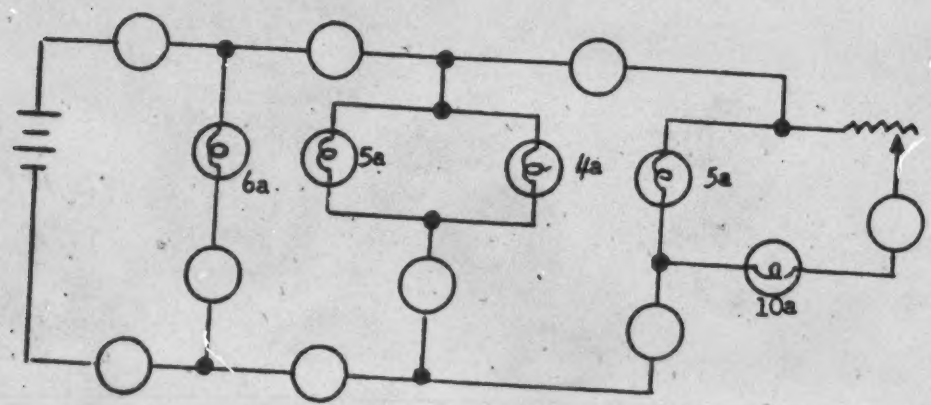
Fill in the ammeter readings for the circuit below on the response sheet. Ammeter A1 has been done for you.

1.



Fill in the ammeter readings in the circuit below.

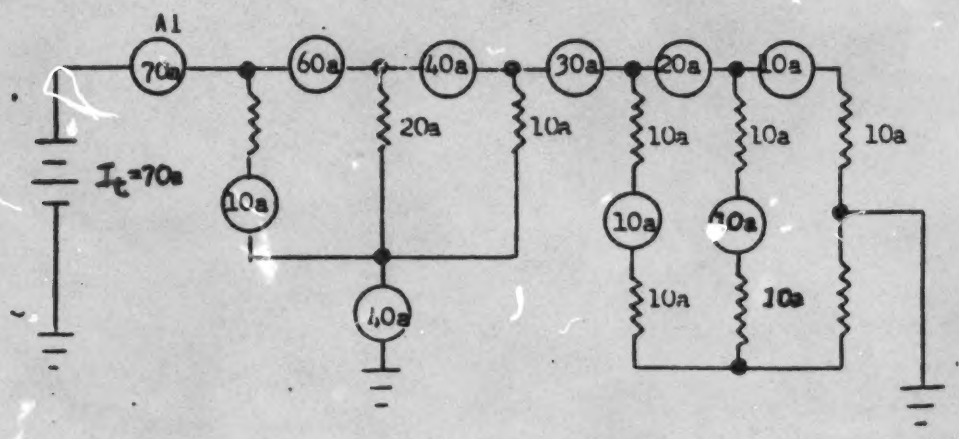
2.



590

Answers to Frame 7:

1.



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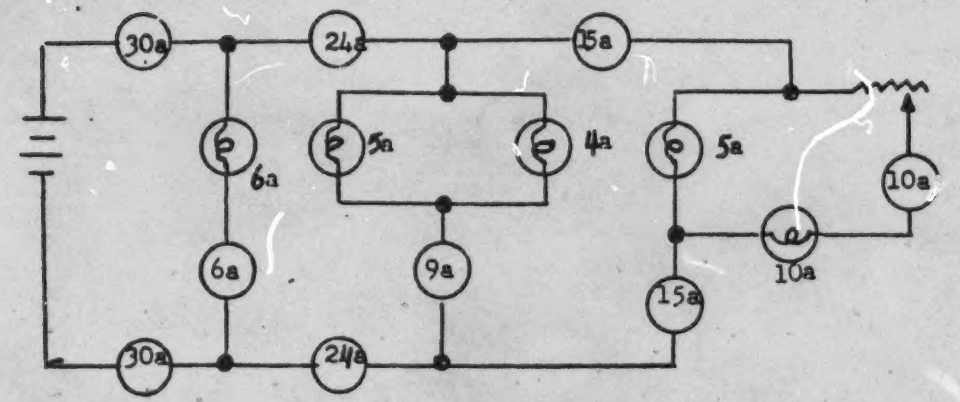


PROGRAMMED TEXT
3ABR42331-PT-115

Technical Training

Aircraft Environmental Systems Mechanic

KIRCHHOFF'S VOLTAGE LAW

2 June 1977

3350 TECHNICAL TRAINING WING
3370 Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE
DO NOT USE ON THE JOB.

FOREWORD

This programmed text was prepared for use in Course 3ABR42331, Aircraft Environmental System Mechanic. The material contained herein has been validated with students from the subject course. Ninety percent of the students achieved the objective criteria as stated or surpassed it. Average time to complete this text was 130 minutes.

OBJECTIVE

Using schematic diagrams and Kirchhoff's voltage law, solve for unknown voltage values in 8 out of 10 electrical circuits.

INSTRUCTIONS

This programmed text presents information in small steps called "frames." Carefully study the written material and or diagram in each frame until you are satisfied that you understand its contents. Each frame requires you to respond to the information in some way. For example, you may be required to solve for unknowns in circuits. Specific instructions are provided in each frame. After you have made your response on the response sheet, compare your answers with the answers given on the top of the next page of the text. If you are correct, go on to the next frame. If you are incorrect, study the frame again and correct your mistakes before continuing. Read carefully, select the correct answers and DO NOT HURRY. DO NOT MARK IN THE TEXT.

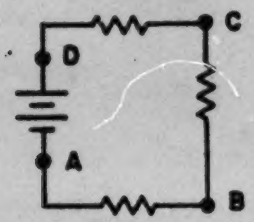
INTRODUCTION

In your last lesson you learned how to apply Kirchhoff's current law in solving for unknowns in a circuit. This lesson is designed to familiarize you with Kirchhoff's voltage law and to show how to apply it to actual circuits.

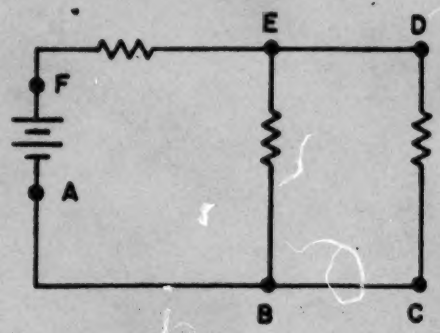
OPR: 3370 TTG
DISTRIBUTION: X
3370 TTGTC - 200; TTVSR - 1 2

Frame 1

Kirchhoff's voltage law is stated as follows: The sum of the voltage drops around any closed path is equal to the total voltage applied to that path. In order to use this law you must understand what is meant by a closed path. To explain this we will use the examples shown below. Example A has just one closed path. It is point A-B-C-D. In example B there are two closed paths. One path is point A-B-E-F. The other path goes from point A-B-C-D-E-F. Trace these two paths in example B to be sure that you understand that there are two closed paths.



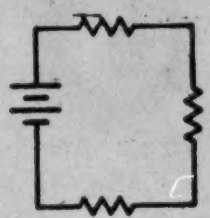
A.



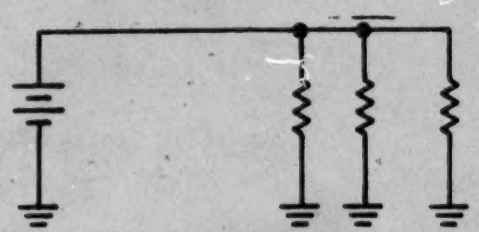
B.

For each of the following circuits indicate in the blanks provided how many closed paths each circuit has.

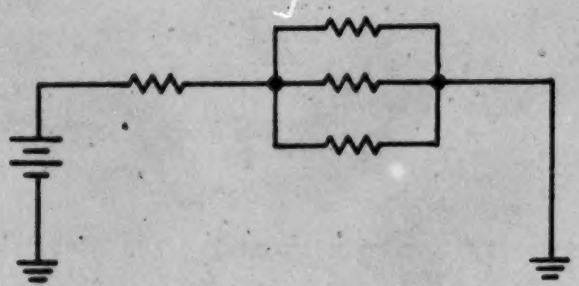
1. How many paths? _____



2. How many paths? _____



3. How many paths? _____

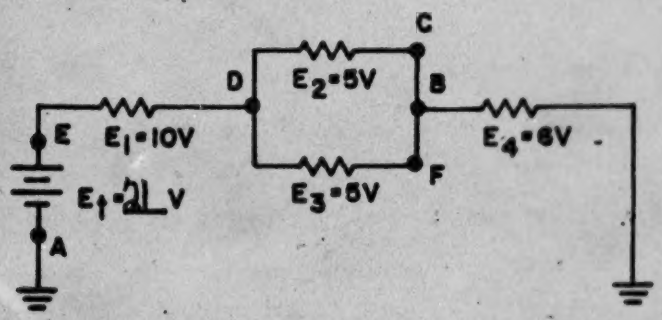


Answers to Frame 1: 1. 1 2. 3 3. 3

Frame 2

Now that you know how to determine the closed paths in a circuit, we will show you how to use Kirchhoff's voltage law to determine unknown voltages. First, we'll restate Kirchhoff's voltage law. The sum of the voltage drops around any closed path is equal to the total voltage applied to that path. To show this we will use the circuit shown below. This figure has two paths. Let's first use the path: A-B-C-D-E.

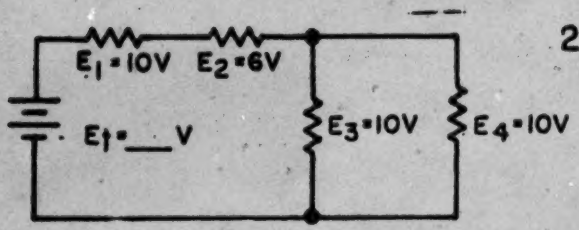
Adding up the voltage drops in this path we have, $E_4 + E_2 + E_1 = 6V + 5V + 10V = 21V$. Kirchhoff's voltage law states that the sum of the drops around any closed path is equal to the total voltage applied. Thus, $E_t = 21V$. Now let's use the other path. It is as follows: A-B-F-D-E. Adding up the voltage drops in this path we have $E_4 + E_3 + E_1 = 6V + 5V + 10V = 21V$. Thus, $E_t = 21V$. As you can see it didn't matter which path we used, we found $E_t = 21V$ using either path. The important thing to remember is to add up the voltage drops around only ONE closed path.



NOTE: REMEMBER THE GROUND SYMBOLS INDICATE THAT THESE POINTS ARE ELECTRICALLY CONNECTED.

Using schematic diagrams below, analyze the circuits to determine total voltage in each circuit. Put your answers on the appropriate blank on the response sheet.

1.



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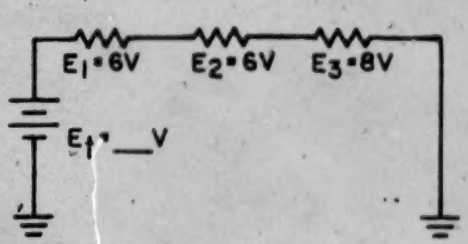
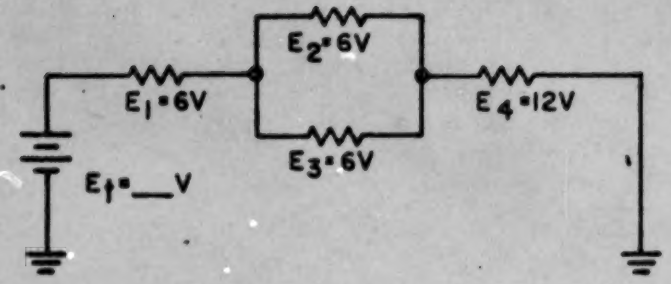


Frame 2 (Continued)

3.



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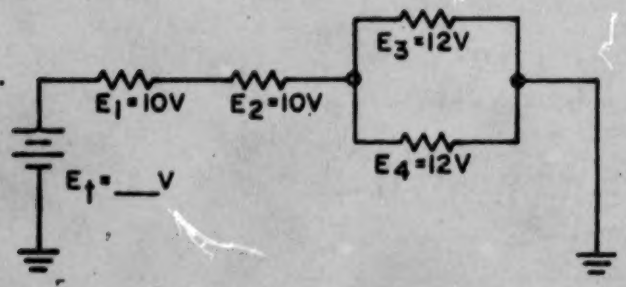
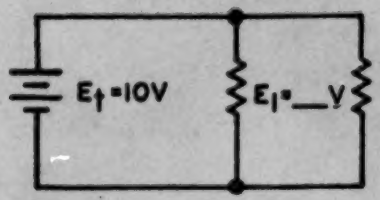


Answers to Frame 2: 1. 26V 2. 20V 3. 24V 4. 32V

Frame 3

Using the schematic diagrams below, analyze the circuits to determine the unknown voltage in each circuit. Put your answers on the appropriate blank on the response sheet. Remember the total voltage is the sum of the voltage in only one close path.

1.



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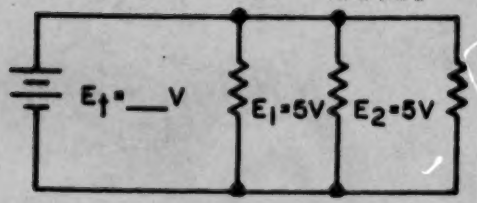


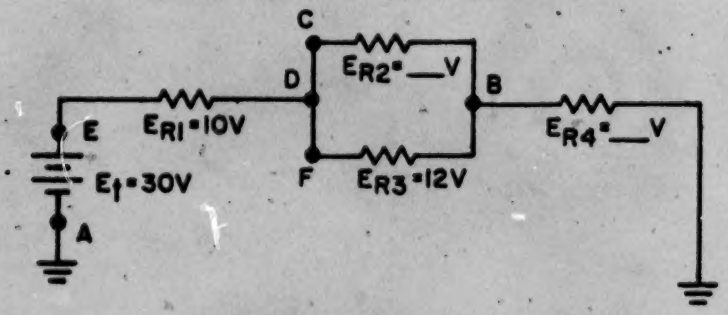
Answers to Frame 3: 1. 10V 2. 5V

Frame 4

In the past frames you saw that Kirchhoff's voltage law is true in actual circuits. The rest of this lesson will give you practice applying Kirchhoff's voltage law. First, we'll give you one more example problem that is worked out step by step. There are two closed paths in the circuit below. One path is A-B-C-D-E.

Applying Kirchhoff's voltage law to this path we have $E_{R4} + E_{R2} + E_{R1} = 30V$. Substituting in known values we have $E_{R4} + E_{R2} + 10V = 30V$. Since there are two unknown voltage drops in this path, we cannot determine the value of either E_{R4} or E_{R2} by using this path. We must use a path that has only one unknown voltage in it. The other path is A-B-F-D-E. Note that this path has only one unknown in it. Applying Kirchhoff's voltage law to this path we have $E_{R4} + E_{R3} + E_{R1} = 30V$. Substituting in known values we have $E_{R4} + 12V + 10V = 30V$. Thus, $E_{R4} = 8V$. Fill in 8V for E_{R4} in the circuit below. Now we have enough information to find E_{R2}. Applying Kirchhoff's voltage law to the path, A-B-C-D-E, we have $E_{R4} + E_{R2} + E_{R1} = E_t$. Substituting in known values we have $8V + E_{R2} + 10V = 30V$. Thus, $E_{R2} = 12V$.

DO NOT WRITE IN THIS TEXT.



NO RESPONSE REQUIRED

Proceed to the next frame.

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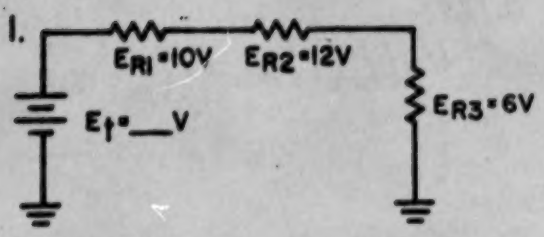
Frame 5

Using Kirchhoff's voltage law, analyze the circuits below to determine the unknown voltage in each circuit. Put your answers on the appropriate blank on the response sheet.

1.



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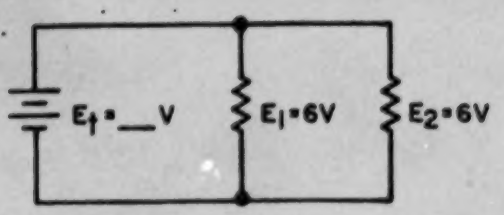

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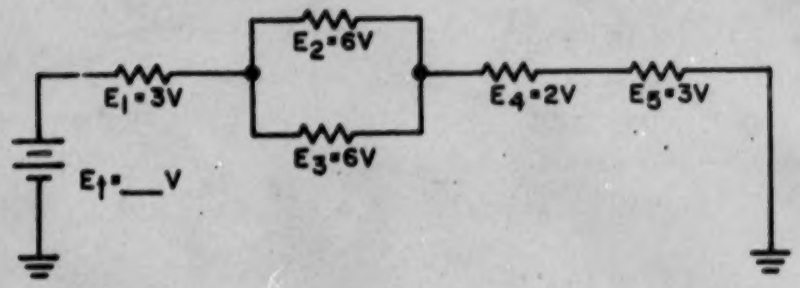

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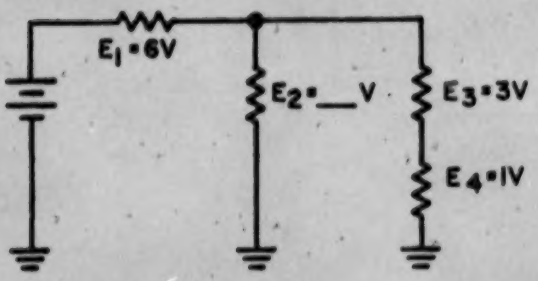
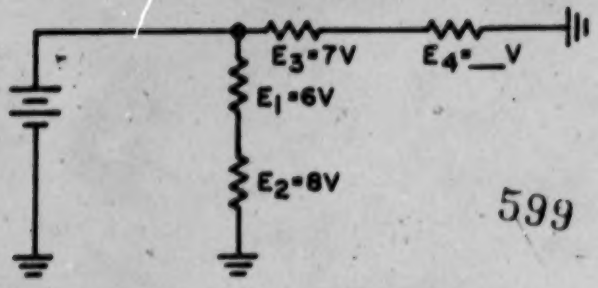


5.



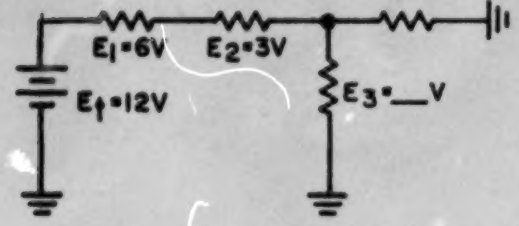
599

Answers to Frame 5: 1. 28V 2. 6V 3. 14V 4. 4V 5. 7V

Frame 6

Using Kirchhoff's voltage law, analyze the circuits below to determine the unknown voltage in each circuit. Put your answers on the appropriate blank on the response sheet.

1.



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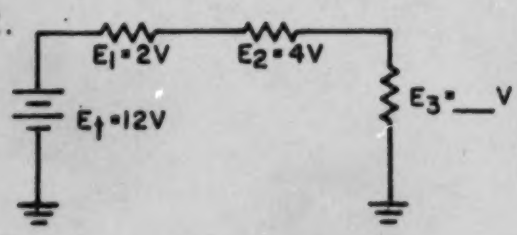

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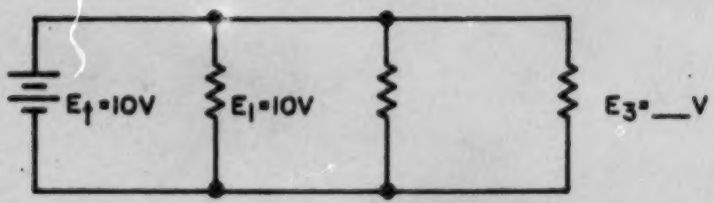

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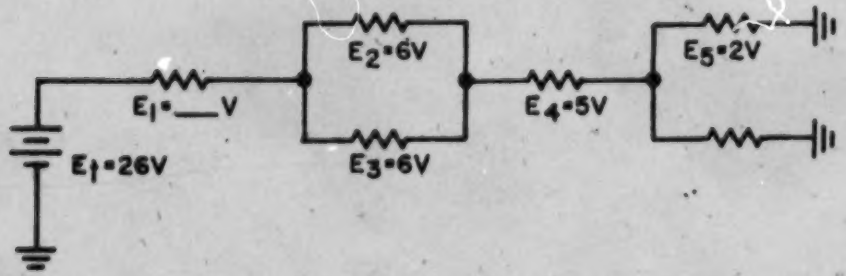

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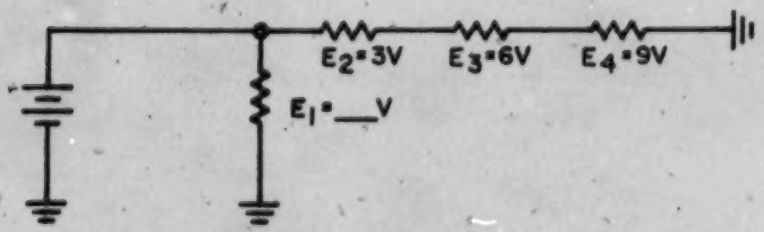
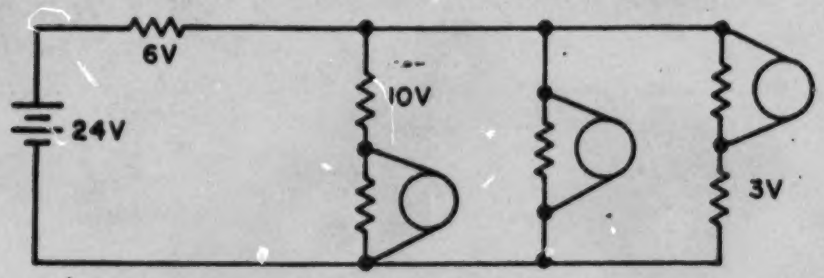


Answers to Frame 6: 1. 3V 2. 6V 3. 10V 4. 13V 5. 18V

Frame 7

Fill in the voltmeter readings in the circuits below on the response sheet.

1.



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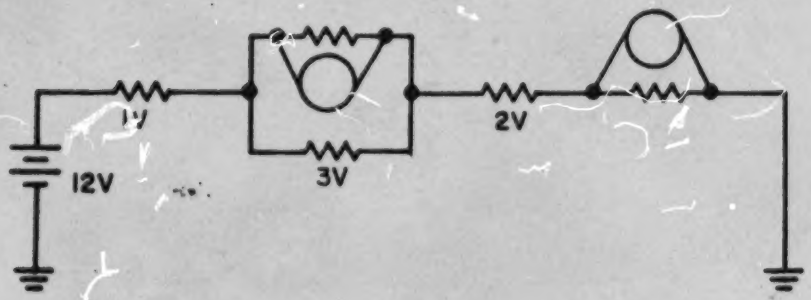

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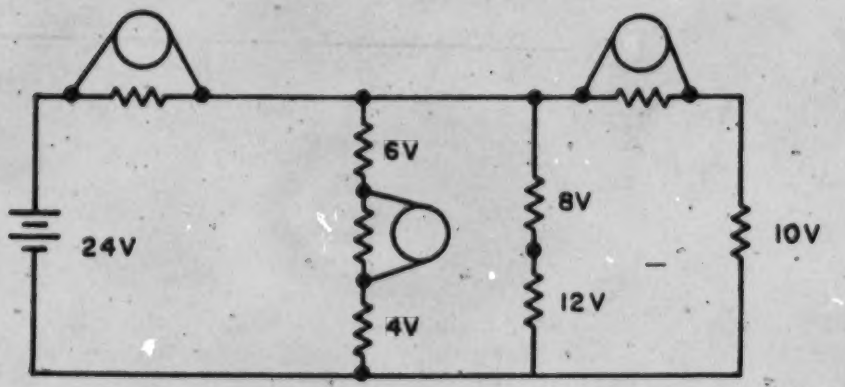


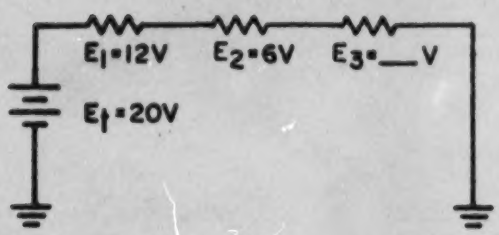
Have the instructor check your answers.

Instructor's Initials _____

Frame 8

Using Kirchhoff's voltage law, analyze the circuits below to determine the unknown voltage in each circuit. Put your answers on the appropriate blank on the response sheet.

1.



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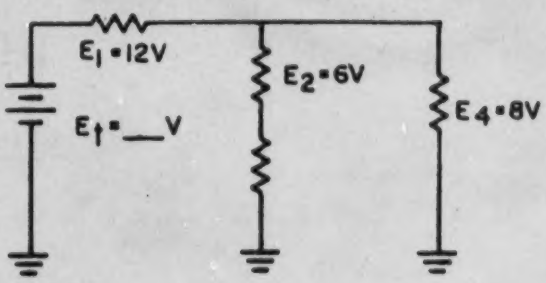

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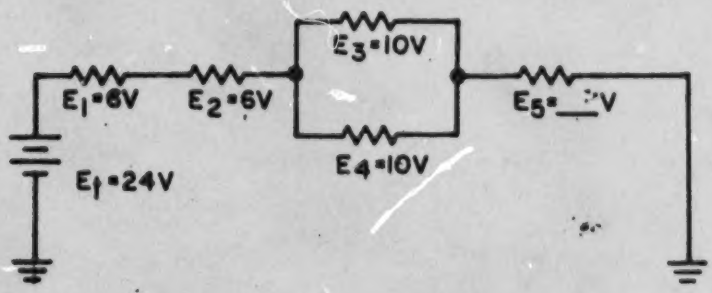

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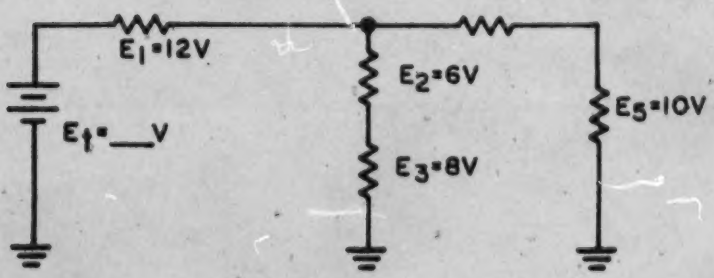

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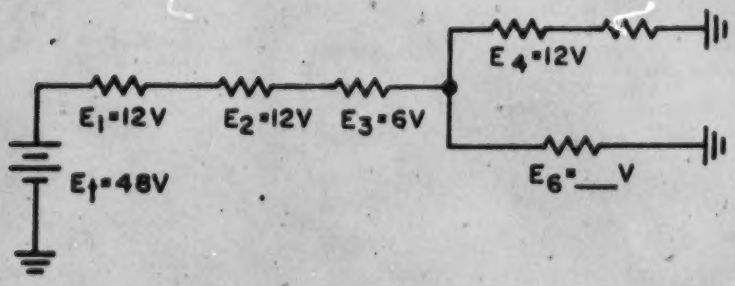
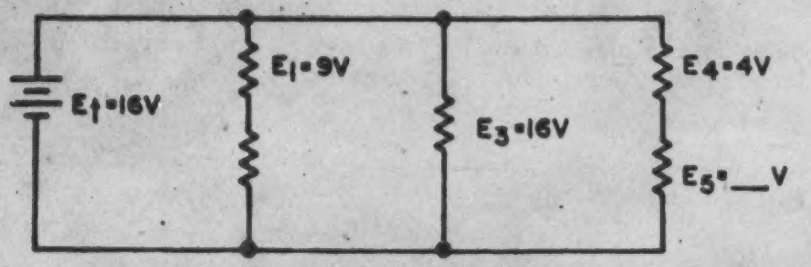


GO TO THE NEXT PAGE.

Frame 8 (Continued)

6.



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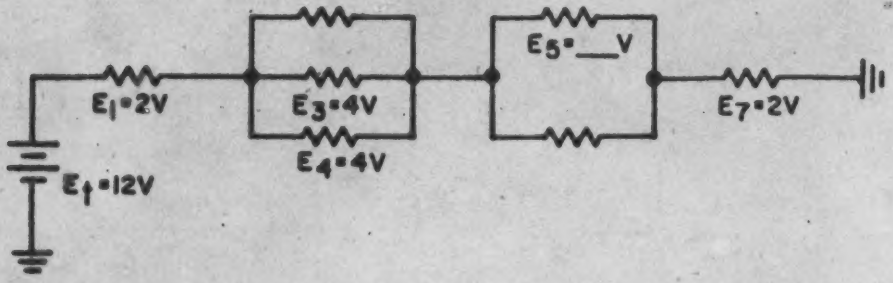
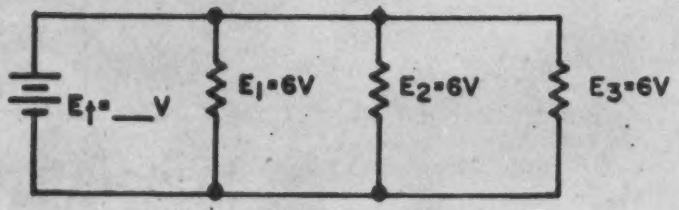


8.



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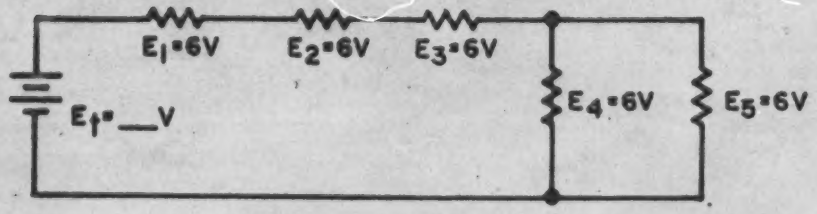

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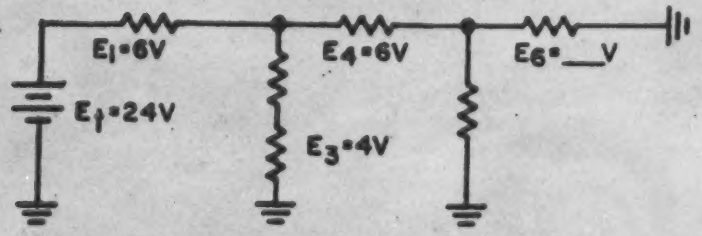

Have the instructor check your answers.

Instructor's Initials _____

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PROGRAMMED TEXT
3ABR42331-PT- 116

Technical Training

Aircraft Environmental Systems Repairman

OHM'S LAW

22 September 1977

3350 TECHNICAL TRAINING WING
3370 Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE
DO NOT USE ON THE JOB

599

FOREWORD

This programmed text was prepared for use in Course 3ABR42331, Aircraft Environmental Systems Repairman. The material contained herein has been validated with students from the subject course. Ninety percent of the students tested achieved all objectives as stated. Average time to complete this was 1 hour and 46 minutes.

OBJECTIVES

Use Ohm's Law and power formulas to solve for unknown values in basic electrical circuits. A minimum of eight out of ten unknown values must be correct.

INSTRUCTIONS

This programmed text presents information in small steps called "frames". Carefully study the written material and/or diagram in each frame until you are satisfied that you understand its contents. Each frame requires you to respond to the information in some way. For example, you may be required to select the true statements or insert a correct answer. Specific instructions are provided in each frame. After you have made your response on the response sheet compare your answers with the answers at the bottom of the next frame. If you are incorrect, study the frame again and correct your mistakes before continuing. Read carefully, select the correct answers and DO NOT HURRY. DO NOT MARK IN THIS TEXT.

OPR: 3370TTG
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FRAME 1

In the following circuits you will see what happens when the voltage, current or resistance values are changed.

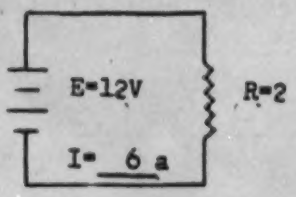

Figure 1.

1. If the circuit below, figure 2, is compared to the circuit above, figure 1, you would see the resistor value has been increased to 6 ohms. This increase will cause the circuit current to drop to 2 amps.

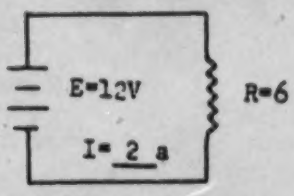

Figure 2.

Note: If the resistor was to drop in its value the current will increase.

2. If the circuit below, figure 3, is compared to the circuit above, figure 1, you can see the applied voltage was increased. This increase will cause the circuit current to increase to 12 amps.

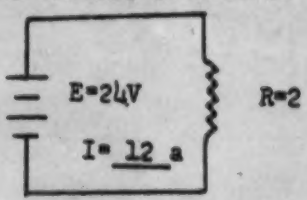

Figure 3.

Note: If the applied voltage was to drop in its value the current will decrease.

From this you can see that there are several relationships between current, voltage and resistance. To be sure you understand them, fill in the blanks on the next page with the correct term. Please place your answers on the response sheet.

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FRAME 1 (Cont'd)

1. Increasing the voltage in a circuit will cuase the current to _____.

2. Decreasing the voltage in a circuit will cuase the current to _____.

3. Decreasing the resistance in a circuit will cause the current to _____.

4. Increasing the resistance in a circuit will cause the current to _____.

FRAME 2

The relationships that we have seen in the last few frames is called Ohm's Law and is stated in general terms as follows: The current in a circuit is <u>directly</u> proportional to the applied voltage and <u>inversely</u> proportional to the circuit resistance. The term "proportional" implies that the current will change by the same factor that the voltage changes. In other words, directly proportional implies that: if the voltage is doubled, the current will be doubled. Inversely proportional implies that: the current will decrease by the same factor that the resistance increases. In other words, if the resistance is doubled, the current is halved.

Fill in the blanks with the correct term on the response sheet.

1. Decreasing the voltage will cause a proportional _____ in the current.

2. If the resistance is halved, the current will be _____.

3. If the voltage is halved, the current will be _____.

4. If the voltage is tripled, the current will be _____.

Answers to Frame 1: 1. increase 2. decrease 3. increase

4. decrease

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FRAME 3

Ohm's Law may be shown as an equation: I = E/R, where I = current in amps, E = voltage in volts, and R = resistance on ohms. For example, in the circuit shown below we want to find the value of I. Substituting the known values into the formula, I = E/R, we have I = 10V/2 = 5a.

Solve each of the following problems for the amount of current flow. Place the answers on the response sheet.

1. E = 12V
   I = ____a
   R = 6Ω

2. E = 6V
   I = ____a
   R = 6Ω

3. E = 6V
   I = ____a
   R = 12Ω

Answers to Frame 2: 1. decrease 2. doubled 3. halved 4. tripled

FRAME 4

In many circuit applications used in this course, current is known and either voltage or resistance will be the unknown. In these cases there are two additional formulas that are derived from the formula I = E/R. To find the value of R when E and I are known, use the formula, R = E/I. To find the value of E when I and R are known, use the formula, E = IxR. A simple memory device that will help you to pick the proper Ohm's Law formula is shown below.

For example, to find E, cover E with a finger as shown in figure a below. The uncovered letters indicate that E = IR. If I is unknown, it is equal to E/R, see figure b below. If R is unknown, it is equal to E/I, see figure c below.

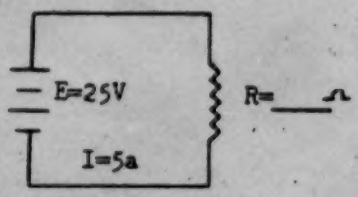
Place the following answers on the response sheet.

The three formulas for Ohm's Law are _____, _____, and _____.

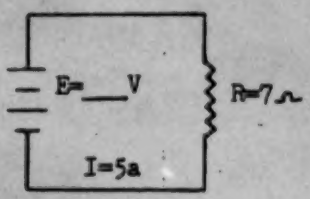
Answers to Frame 3: 1. 2A 2. 1A 3. .5A

Now let's solve some problems for unknown voltages and currents.

In the diagram below, the unknown resistance can be found by using the formula, R = E/I. Substituting in the known values for E and I, we have R = 25V/5a = 5 ohms.

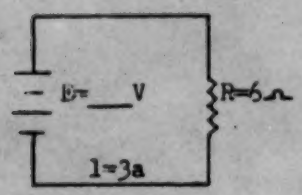


In the diagram below, the unknown voltage can be found by using the formula, E = IxR. Substituting in the known values for I and R, we have E = 5a x 7 = 35V.

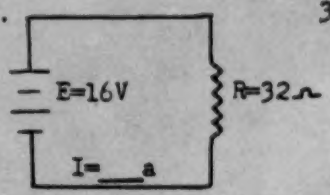


Solve each of the following problems for the unknown. Put your answers in the appropriate blank on the response sheet.

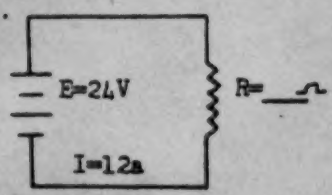
1.



2.



3.

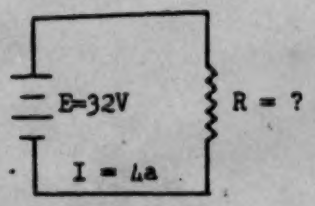


Answers to Frame 4: 1. E = IxR 2. I = E/R 3. R = E/I (any order)

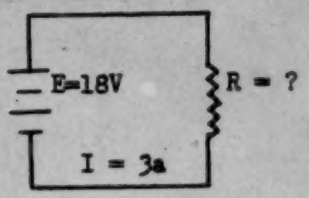
FRAME 6

Calculate the resistance in each of the following circuits. Put your answers in the appropriate blank on the response sheet.

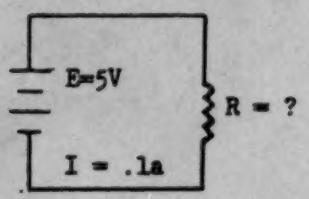
1. R = _____Ω



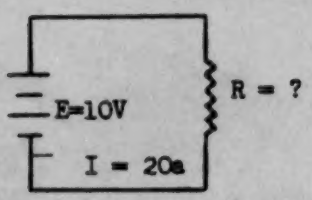
2. R = _____Ω



3. R = _____Ω



4. R = _____Ω

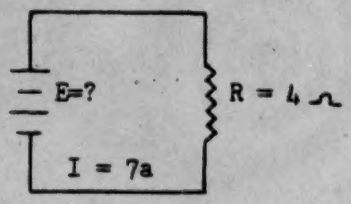


Answers to Frame 5: 1. 18V 2. .5a 3. 2 ohms

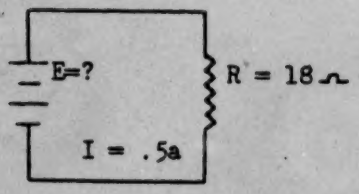
FRAME 7

Calculate the voltage in each of the following circuits. Put your answers in the appropriate blank on the response sheet.

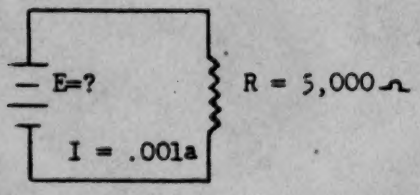
1. E = _____V



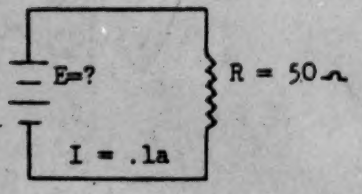
2. E = _____V



3. E = _____V



4. E = _____V



Answers to Frame 6: 1. 8 ohms 2. 6 ohms 3. 50 ohms 4. 5 ohms

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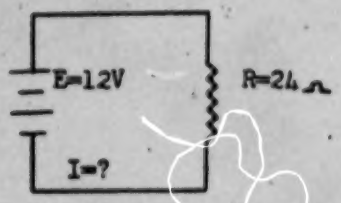
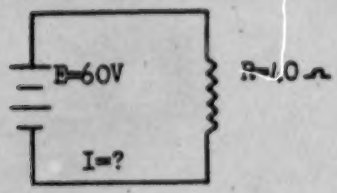
FRAME 8

Calculate the current in each of the following circuits. Put your answers in the appropriate blank on the response sheet.

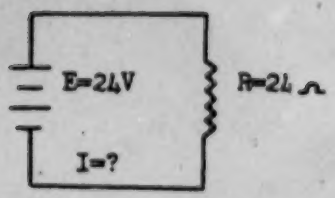
1. I = _____a



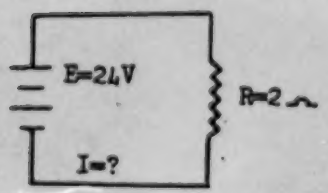
2. I = _____a



3. I = _____a



4. I = _____a

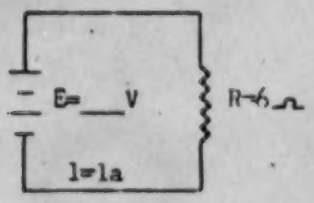


Answers to Frame 7: 1. 28V 2. 9V 3. 5V 4. 5V

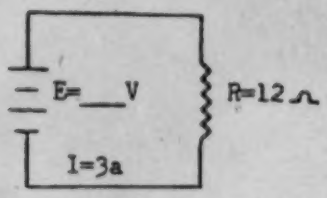
FRAME 9

Solve for the unknown in each of the following circuits. Put your answers in the appropriate blank on the response sheet.

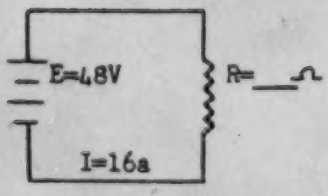
1.



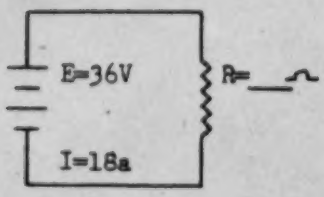
2.



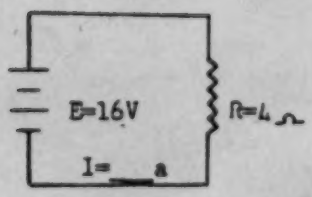
3.



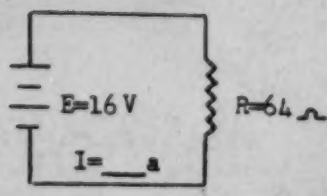
4.



5.



6.



Answers to Frame 8: 1. .5a 2. 1.5a 3. 1a 4. 12a

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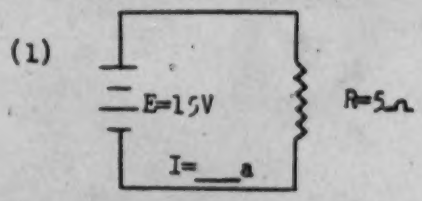
FRAME 10

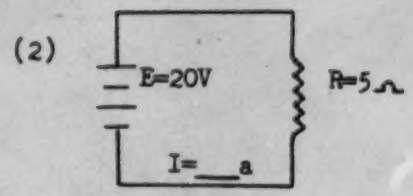
Perform each of the following steps in the sequence given. Fill in the blanks with the correct word or number on the response sheet.

1. In circuit (1) solve for the current.



If you got I = 3a, you are correct, go to step 2. If you didn't get I = 3a, find your mistake before going to step 2.

2. In circuit (2) solve for the current.



If you got I = 4a; you are correct, go to step 3. If you didn't get I = 4a, find your mistake before going to step 3.

3. The only difference between circuit (1) and circuit (2) was the amount of voltage applied. When the voltage was increased from 15V to 20V, the current was increased from 3 amps to 4 amps.

No further response required, proceed to the next frame.

Answers to Frame 9: 1. 6V 2. 36V 3. 3 ohms 4. 2 ohms 5. 4a 6. .25a

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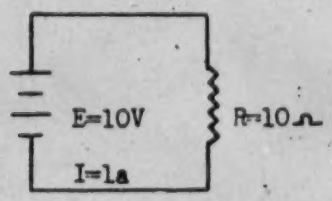
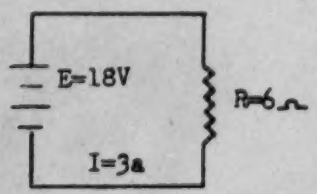
FRAME 11

Fill in the blanks with the correct word or number on the response sheet.

1. In the circuit below, if the voltage is increased to 20V, the current will (decrease/increase) _____ to _____ amperes.



2. In the circuit below, if the voltage is decreased to 12V, the current will (decrease/increase) _____ to _____ amperes.



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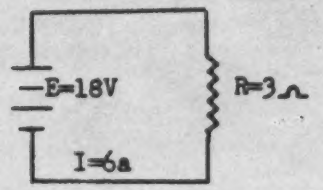
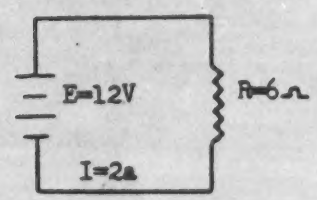
FRAME 12

Fill in the blanks with the correct word or number on the response sheet.

1. In the circuit shown below, if the 3 ohm resistor is replaced by a 6 ohm resistor, the current will (decrease/increase) _____ to _____a.



2. In the circuit shown below, if the 6 ohm resistor is replaced by a 2 ohm resistor, the current will (decrease/increase) _____ to _____a.



Answers to Frame 11: 1. increase 2A 2. decrease 2A

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FRAME 13

Fill in the blanks with the correct term or formula on the response sheet. The first two have been done for you.

1. Ohm's Law states that: The current in a circuit is directly proportional to the voltage and inversely proportional to the resistance.

2. The three formulas for Ohm's Law are E = IxR, I = E/R, and R = E/I.

3. Increasing the resistance in a circuit will cause a proportional (increase/decrease) _____ in current.

4. Decreasing the voltage in a circuit will cause a proportional (increase/decrease) _____ in current.

Solve the following problems for the unknown. Put your answers in the appropriate blank on the response sheet.

5. E = _____V
   I = .25a
   R = 40Ω

6. E = 18V
   I = _____a
   R = 12Ω

7. E = 28V
   I = 14a
   R = _____

Answers to Frame 12: 1. decrease 3a 2. increase 6a

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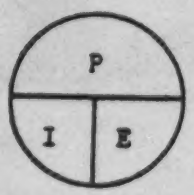
FRAME 14

Power is the rate at which work is done. Work is done when a force causes motion. Previously it was shown that voltage is an electrical force and that voltage will force current to flow in a closed path. When there is voltage between two points, but current can not flow, no work is done. A total amount of work may be dony in different lengths of time. For example, a given amount of electrons may be moved from one point to another in 1 second or 1 hour depending on the rate at which they are moved. In both cases the total work done is the same. When the work is done in a shorter time, the rate is greater than when the same amount of work is done in a longer time. The basic unit of power is the watt. The symbol for power is P. The basic power formula is P = I x E. I is the current through, and E is the voltage across the resistor or unit for which power is being measured. The abbreviation used for the watt is w.

Note: The formula for power will be easy to remember by spelling the work PIE. We also have the memory device shown below.



Mark the true statements with a "T" on the response sheet.

____ 1. Work is done when a battery forces electrons to move through a circuit.

____ 2. The terms work and power have identical meanings.

____ 3. The power in a circuit is equal to the current multiplied by the voltage.

Answers to Frame 13: 1. Voltage Resistance 2. E=IxR I=E/R R=E/R 3. decrease 4. decrease 5. E=10V 6. 1.5a 7. 2 ohm

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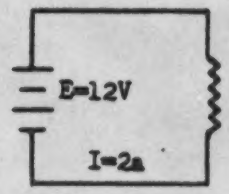
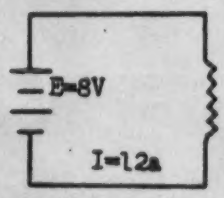
FRAME 15

In the circuit shown below, the value of the power that the battery supplies to the resistor can be found by means of the equation P = I x E. To find the power output of the battery, substitute the current, 2 amps, for I, and substitute the battery voltage, 12 volts, for E. The power in watts is equal to ? x 12= 24w.

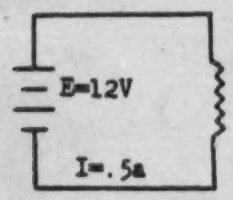


Find the power supplied by the battery in each of the following circuits. Put your answers in the appropriate blank on the response sheet.

1. P = _____w



2. P = _____w



Answers to Frame 14: 1. T 2. F 3. T

615

FRAME 16

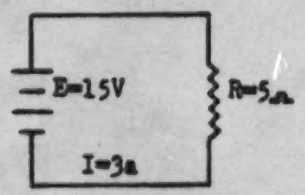
Fill in the blanks with the correct term or formula on the response sheet.

1. Ohm's Law states that: The current in a circuit is directly proportional to the _____ and inversely proportional to the _____.

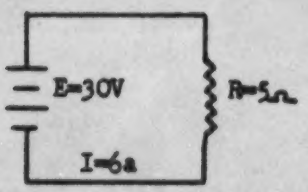
2. Increasing the resistance in a circuit will cause a proportional (increase/decrease) _____ in current.

3. Increasing the voltage in a circuit will cause a proportional (increase/decrease) _____ in current.

4. In the circuit shown below, if the voltage is decreased to 10V, the current will (decrease/increase) _____ to _____ amperes.



5. In the circuit shown below, if the 5 ohm resistor is replaced by a 15 ohm resistor, the current will (decrease/increase) _____ to _____ amperes.

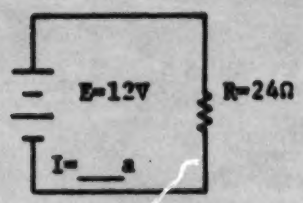


Answers to Frame 15: 1. 96w 2. 6w

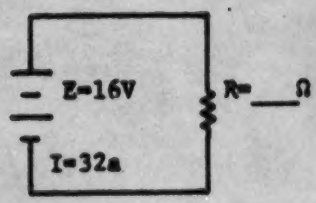
FRAME 17

Solve for the unknowns in each of the following problems. Put your answers in the appropriate blank on the response sheet.

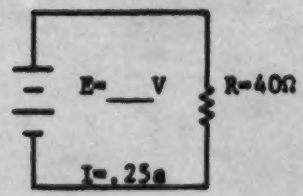
1.



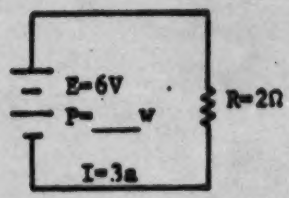
2.



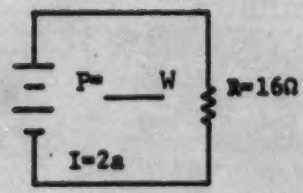
3.



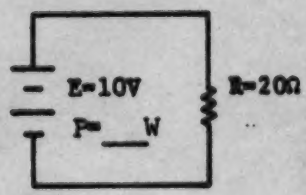
4.



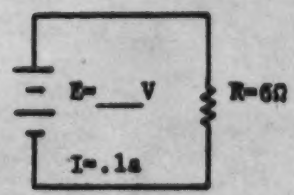
5.



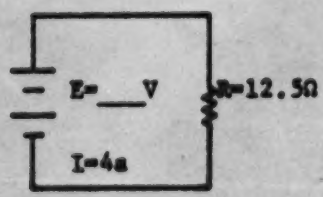
6.



7.



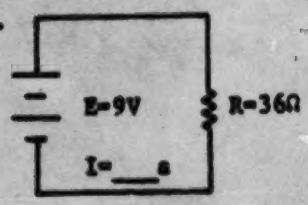
8.



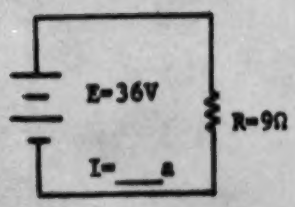
617

FRAME 17 (Con't)

9.



10.



Answers to Frame 16:

1. voltage resistance
2. decrease
3. increase
4. decrease 2A
5. decrease 2A

Answers to Frame 17:

1. .5a
2. .5Ω
3. 10V
4. 18w
5. 64w
6. 5w
7. .6V
8. 50V
9. .25a
10. 4a

623

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PROGRAMMED TEXT
3ABR42331-PT-117
3ABR44330G-2-PT-104

Technical Training

Aircraft Environmental Systems Mechanic

Missile Mechanic (WS-133)

SERIES CIRCUIT

15 February 1979

CHANUTE TECHNICAL TRAINING CENTER (ATC)
3370 Technical Training Group
Chanute Air Force Base, Illinois

Designed for ATC Course Use.
Do Not Use on the Job.

619.

FOREWORD

This programmed text was prepared for use in the 3ABR42231 instructional system. The material contained herein has been validated using thirty-five 42010 students enrolled in the 3ABR42231 course. Ninety percent of the students taking this text surpassed the criterion called for in the approved lesson objective. The average student required fifty minutes to complete the text. After completing this text the student will be able to attain the objectives with an accuracy of 70%.

OBJECTIVES

Upon completing this programmed text you will be able to:

1. Define a series circuit.

2. Identify electrical symbols.

3. Identify a series circuit diagram.

4. Describe the characteristics of voltage, amperage, and resistance in a series circuit.

5. Apply Ohm's Law to solve unknown values using a series circuit diagram.

INSTRUCTIONS

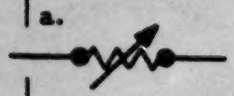
This program presents information in small steps called "frames." After reading each frame, you are asked to select an answer or make an entry that shows you understand the information in that frame; do so by writing your answer in this book. You may check the accuracy of your answer by looking on the next page.

Supersedes 3ABR42231-PT-114, 8 March 1971.
OPR: 3370 TCHTG
DISTRIBUTION: X
3370 TCHTG/TTGU-P - 100; TTVSA - 1

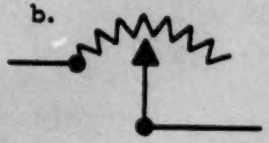
A fixed resistor has a value that is considered "fixed," that is, its value does not change under normal circumstances. It can be easily identified in a diagram because it <u>does not</u> have an arrow.

From among the symbols of resistors shown below, circle the letter of the resistor that has a fixed value.

a.

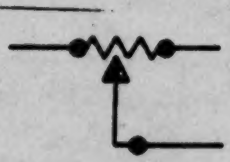


b.

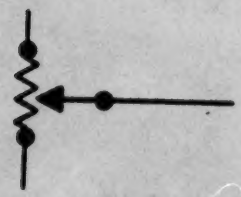


c.

d.



e.



621.

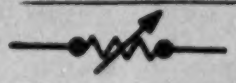
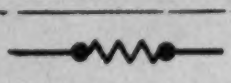
Answer to Frame 1: c. is a fixed resistor.

Frame 2

A variable resistor can be recognized by the arrow.

The arrow means the value of the resistor can be changed. This kind of resistor is found frequently in an aircraft air conditioning system.

Circle the letter beside the variable resistor.

a.  b. 

a.

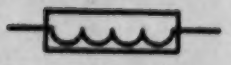
Frame 3

The symbol that represents a lamp (often referred to as a bulb) is a circle with a small loop of wire inside. The loop represents the small wire that glows in a lamp and the circle means the loop is inside an enclosure, in this case a glass with a partial vacuum.

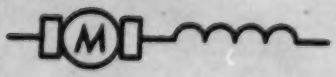
Circle the letter of the symbol that represents a lamp.

a.

b.

c. 

d.

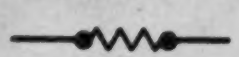
e. 

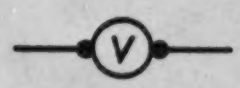
627

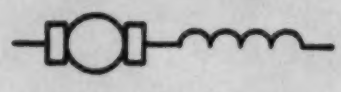
Answer to Frame 3: d. is a lamp.

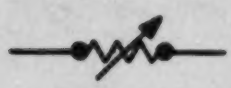
Frame 4

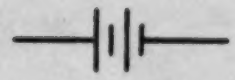
Below are several symbols. Write the letter of the symbol in the appropriate space of the right hand column.

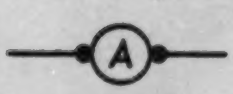
a. 

b. 

c. 

d. 

e. 

f. 

g.

h.

1. _____ Variable resistor

2. _____ Lamp

3. _____ Fixed resistor

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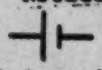
Answer to Frame 4: 1. d 2. g 3. a

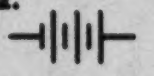
Frame 5

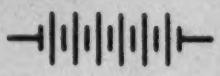
The battery symbol is shown below. Notice the difference in the two lines.



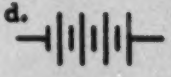
One is long and represents the Positive side of the cell.
The other is short and represents the Negative terminal of the cell.
The two lines make up one cell and usually indicate one and one-half volts.
A "Battery" then is made up of many cells.

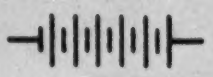
From the symbols below, circle the letter of the battery that has a voltage of 9 volts and has its terminals correctly drawn.

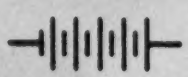
a. 

b. 

c.

d. 

e. 

f. 

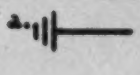
//

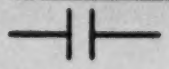
e.

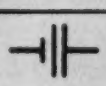
Frame 6

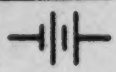
The ground symbol has a long vertical or horizontal line and two or three vertical or horizontal lines that are each smaller than the one before it.

Circle the letter beside the ground symbol below.

a. 

b. 

c. 

d. 

//

a.

Frame 7

Below are some names with which you should now be familiar. Draw the correct symbol in the appropriate space beside the name.

a. fixed resistor _____

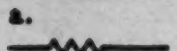
b. lamp _____

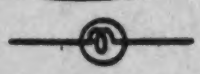
c. variable resistor _____

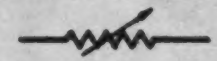
d. three volt battery _____

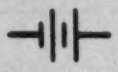
e. "Ground" _____

Answer to Frame 7:

a. 

b. 

c. 

d. 

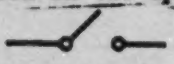
e.

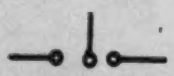
Frame 8

You will see many switches in diagrams for the circuits we work on. They are drawn in symbol form so that you can see how they switch current within the circuit.

Current enters the part of the switch called a "Pole," and the position it can be "thrown to" so a circuit will be completed, is called a "throw."

From this description, identify the single-pole-single throw" (SPST) and the "single-pole-double-throw" (SPDT) switches by writing the letter of the symbol in the appropriate space in the right hand column.

a. 

b. 

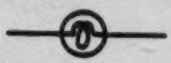
1. _____ SPDT

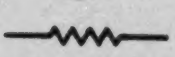
2. _____ SPST

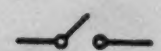
1. b 2. a

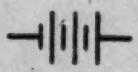
Frame 9

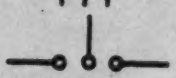
There are seven symbols below and a space to the right of them. Identify the symbol and write the correct name in the space beside the symbol.

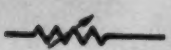
a. 

b. 

c. 

d. 

e. 

f. 

g.

625 Answers to Frame 9:

a. Lamp b. fixed resistor c. switch SPST d. battery (4 1/2V)

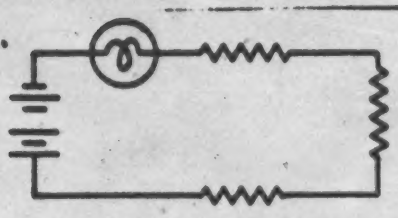
e. switch SPDT f. resistor, variable g. ground

Frame 10

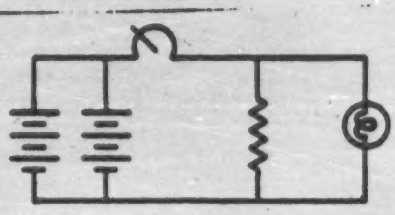
A series circuit is a circuit that has only one path for current to follow. All of the components that make up a series circuit are arranged in such a way that current must travel through each part and not be given any other path to travel.

From the diagrams below, choose the ones that are "Series Circuits."

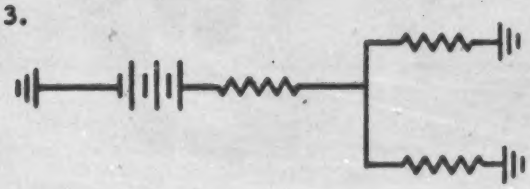
1.



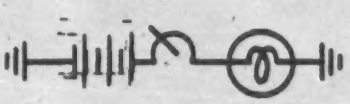
2.



3.

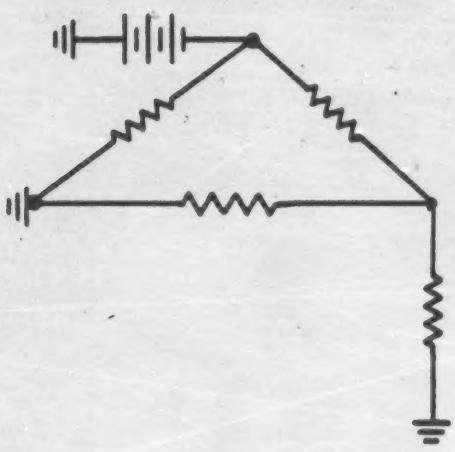


4.



5.

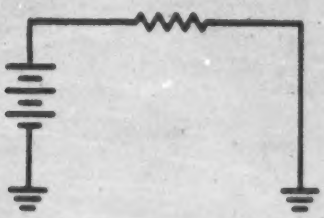
6.

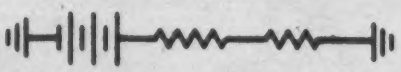


Answers to Frame 10: 1, 4, and 5 are series circuits.

Frame 11

These are series circuit diagrams.





Circle the letter of the statement that correctly describes series circuits.

a. Series circuits are arranged in such a way that current must travel through the only path provided.

b. Current can travel through any of the two or more paths provided.

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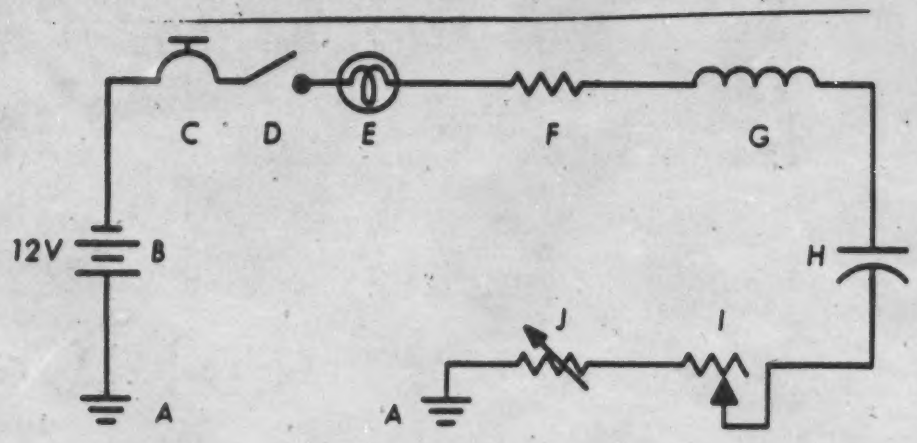
Answer to Frame 11: a is the only correct answer.

Frame 12

We see that all the components are arranged in a sequence called "Series." Let's look into these components and see how they are represented by symbols in a diagram. In the diagram below we have drawn several items using only their symbols.

Fill in the blanks beside the letter with the names of the components that correspond to the symbols in the diagram. Compare your answers with the correct ones on the next page.



A. ___ B. ___ C. ___ D. ___ E. ___ F. ___ G. ___ H. ___

I. ___ J. ___

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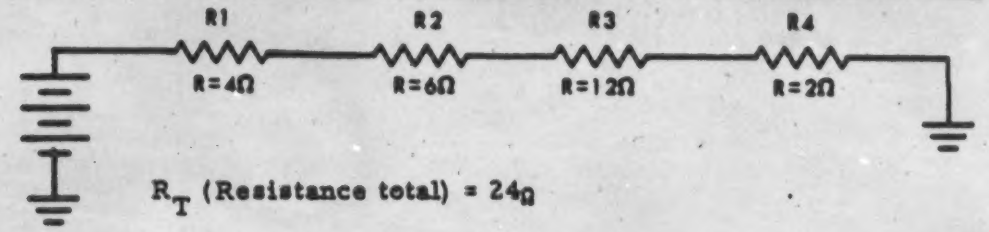
Answers to Frame 12:

A. ground B. battery C. circuit breaker D. switch E. lamp
F. fixed resistor G. coil H. capacitor I. rheostat
J. variable resistor

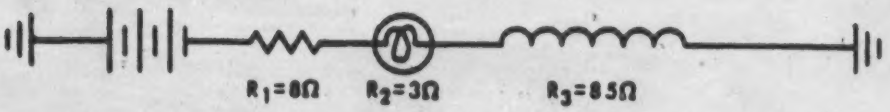
Frame 13

At this point you are familiar with Ohm's Law, circuit symbols, and series circuit construction. We will use this information to recognize the characteristics of a series circuit and to solve some circuit problems. In the circuits below, notice that each resistor is directly in the path of the current flow.

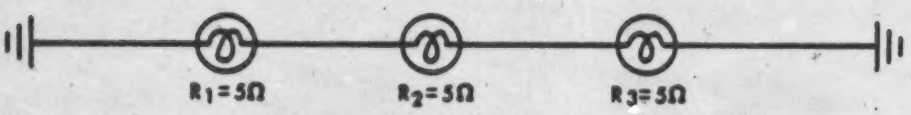
This means that the voltage must work hard to push current (amperage) through each of the resistors. Therefore, the total resistance in a series circuit is found by simply adding the value of all the resistors.



R_T (Resistance total) = 24Ω



R_T=96Ω



R_T=15Ω

Circle the letter of the statement that best describes the characteristics of resistance in a series circuit.

a. Total resistance is the same as any one of the individual resistors in the circuit.

b. Total resistance is the "SUM" of all the individual resistors in the circuit.

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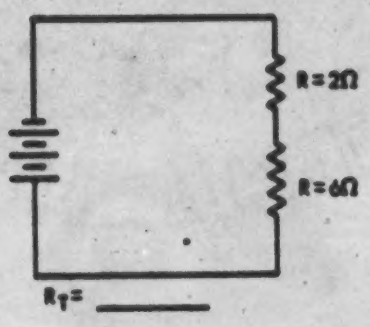
Answer to Frame 13: b. is correct

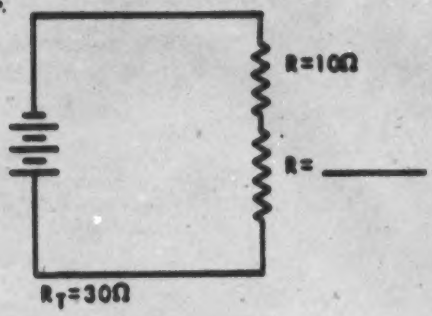
Frame 14

Now that you recognise total resistance as always in a series circuit the "SUM" of the individual resistances, solve the problems below. Place your answer in the proper space beside each diagram.

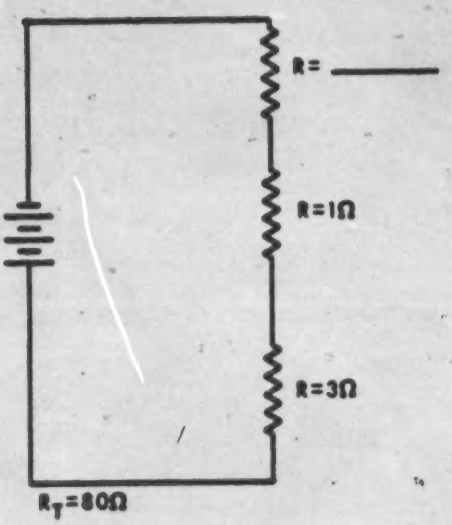
1.



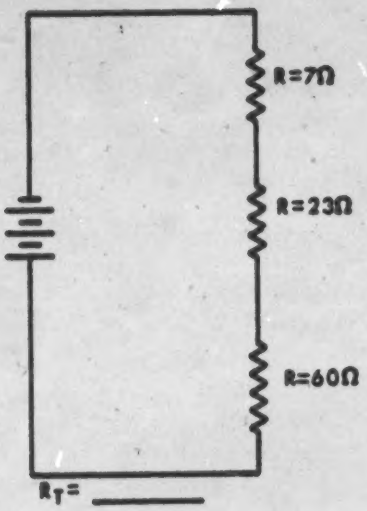
2.



3.



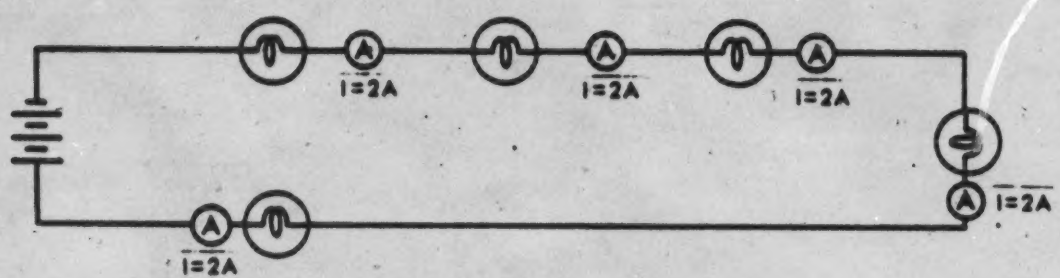
4.



Answers to Frame 14:
1. $R_t = 8\ \Omega$ 2. $R = 20\ \Omega$ 3. $R = 76\ \Omega$ 4. $R_t = 90\ \Omega$

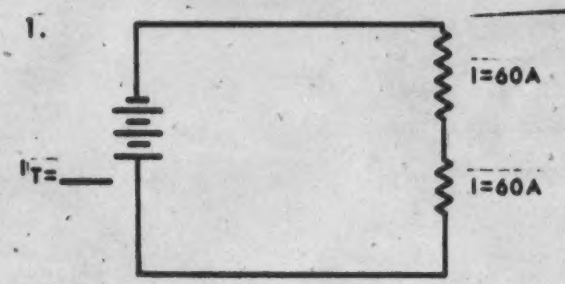
Frame 15

A second thing we should know, and perhaps the most important, is how current flows in a series circuit. Current flow (amperage) is the "SAME" all through the circuit. Logically, it must be since no more electrons can return to the battery than originally left it. Suppose a meter has been used in each of the illustrations below. The meter indications near the circuit components show that current is the same throughout a series circuit.

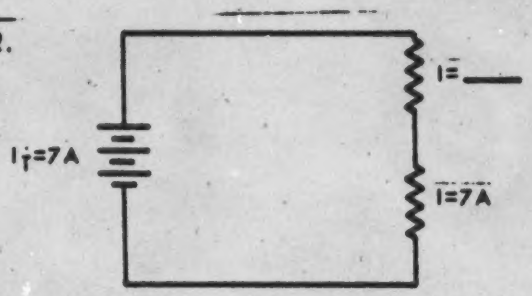


Solve the problems below and write your answer in the appropriate spaces. Check your answers with those on the next page.

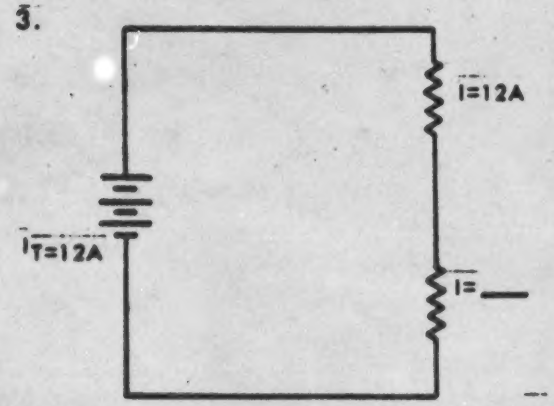
1.



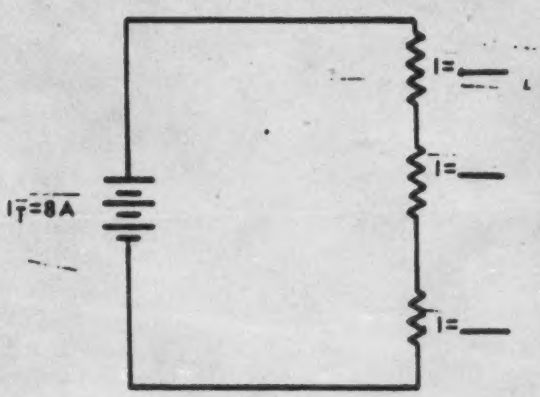
2.



3.



4.



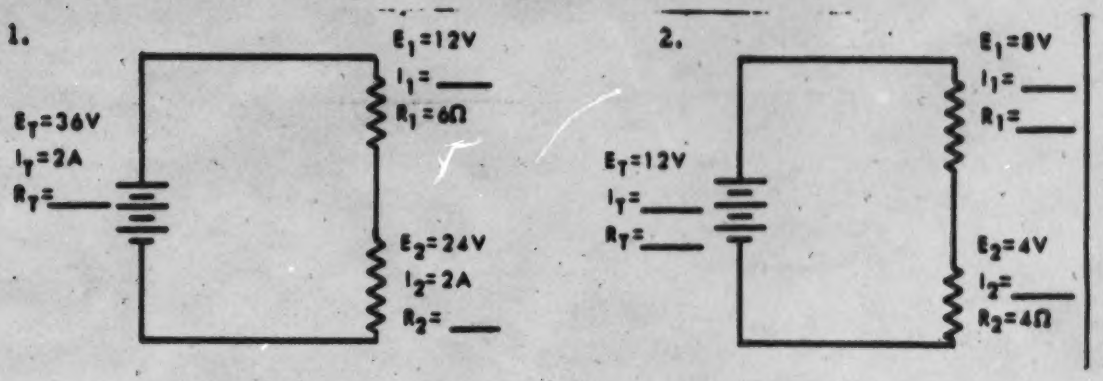
Answers to Frame 15:

1. $I_t = 60a$ 2. $I = 7a$ 3. $I = 12a$ 4. $I = 8a$, $I = 8a$, $I = 8a$

Frame 16

In a series circuit total resistance is the SUM of the individual resistances. Amperage is always the SAME throughout the circuit. Below are some problems that can be easily solved by using this information and Ohm's Law.

Write your answers in the appropriate spaces below.



//

1. $R_t = 18\Omega$, $I_1 = 2a$, $R_2 = 12\Omega$

2. $I_t = 1a$, $R_T = 12\Omega$, $I_1 = 1a$, $R_1 = 8\Omega$, $I_2 = 1a$

Frame 17

Circle the letters of the statements below that correctly describe the characteristics of Resistance and Amperage in a series circuit.

a. Amperage remains the same throughout the entire circuit.

b. Amperage is the sum of the amperages throughout the circuit.

c. Resistance is the same throughout the entire circuit.

d. Resistance is the sum of the individual resistors in the circuit.

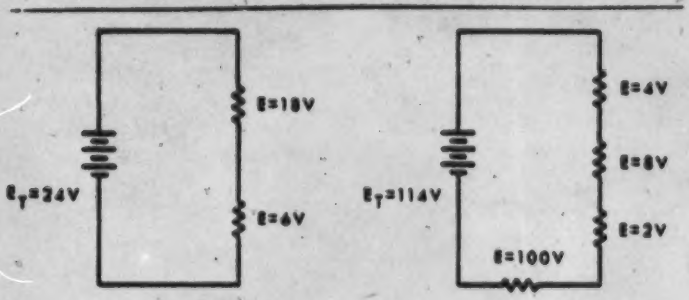
//

a and d

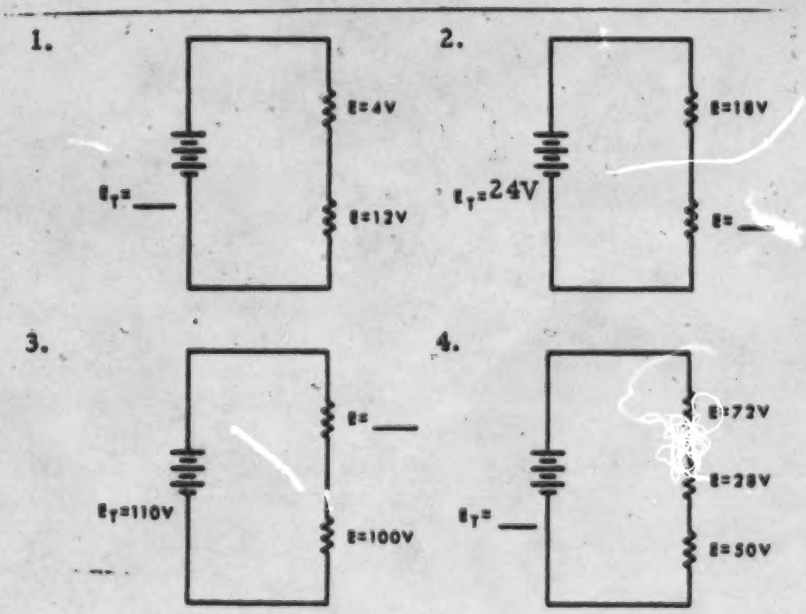
The final characteristic that must be considered in a series circuit is the effect of voltage. You have learned earlier that voltage does not travel through a circuit, but rather pushes (or pulls) the current through the resistors. A certain amount of this voltage is "dropped" (used up) as it pushes current through each resistor. Naturally the voltage drop won't be the same for each resistor since it will require more voltage to force current through a large resistor than it will through a smaller one.

From this, we can conclude that total voltage is the SUM of the voltages required to force current through each of the resistors.

Notice in the diagrams below how voltage drops are determined.



Solve the Voltage Problems below using the characteristic--Voltage is the SUM of the individual voltage drops and write the voltage values in the appropriate spaces.



633 Answers to Frame 18:
1. E_t = 16V 2. E = 6V 3. E = 10V 4. E_t = 150V

Frame 19

From the characteristics listed below, indicate whether the total in a series circuit is the SUM or the SAME by writing the word SUM or SAME in the space beside the characteristic it describes.

a. _____ Total Amperage is the (Sum of - Same as) all the amperages throughout the circuit.

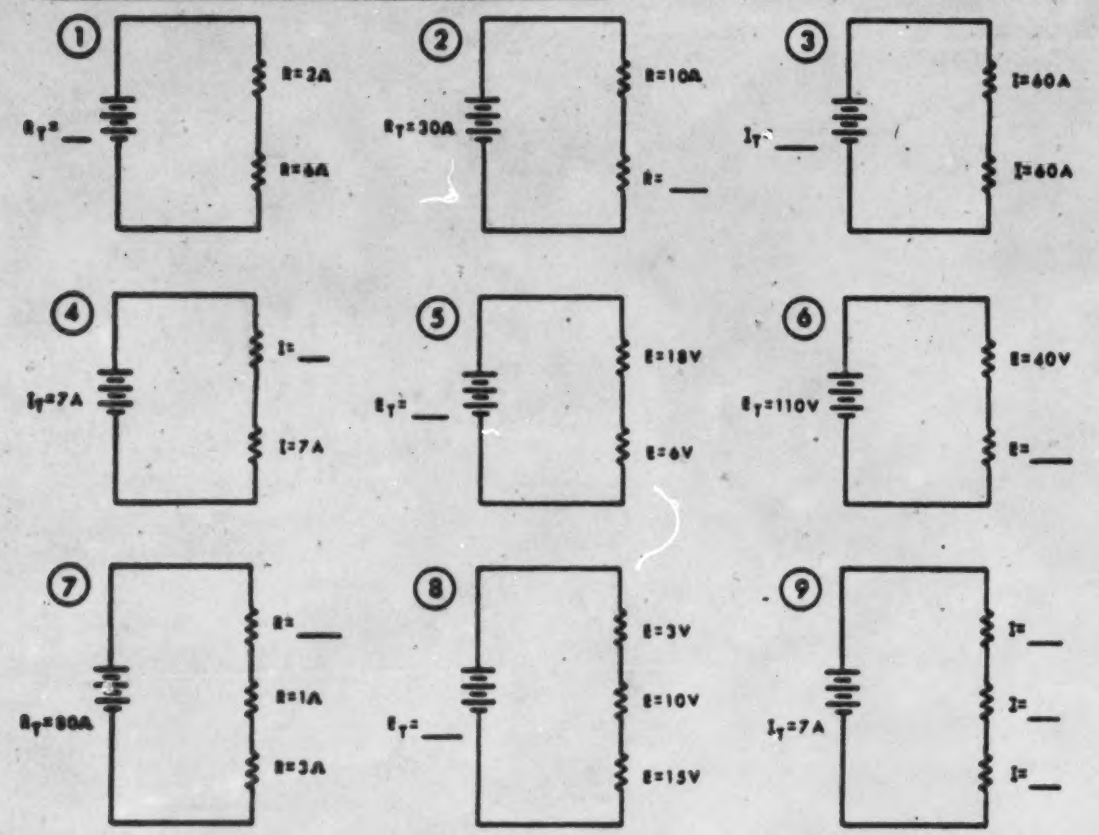
b. _____ Total Voltage is the (Sum of - Same as) all the voltages dropped throughout the circuit.

c. _____ Total Resistance is the (Sum of - Same as) all the resistances in the circuit.

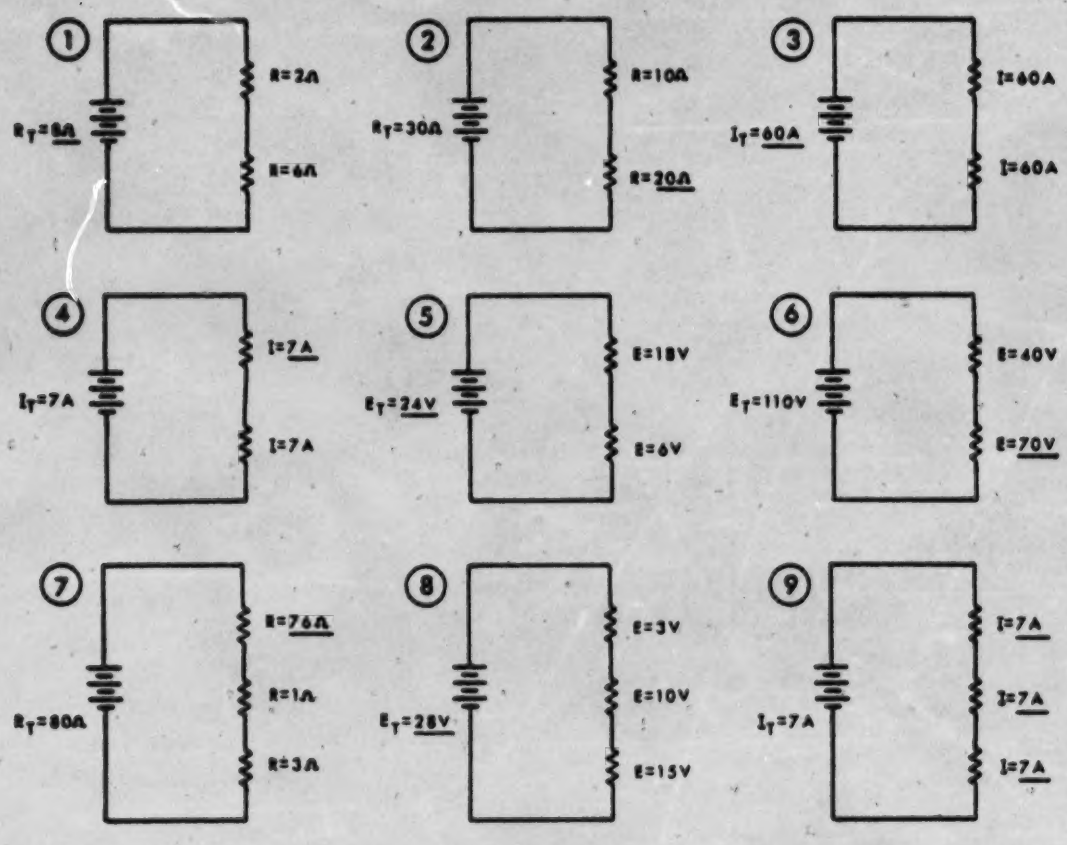
a. Same b. Sum c. Sum

Frame 20

Use OHM'S LAW and the characteristics of a Series Circuit to solve the following Series Circuit problems. Write your answers in the spaces provided.



Answer to Frame 20:



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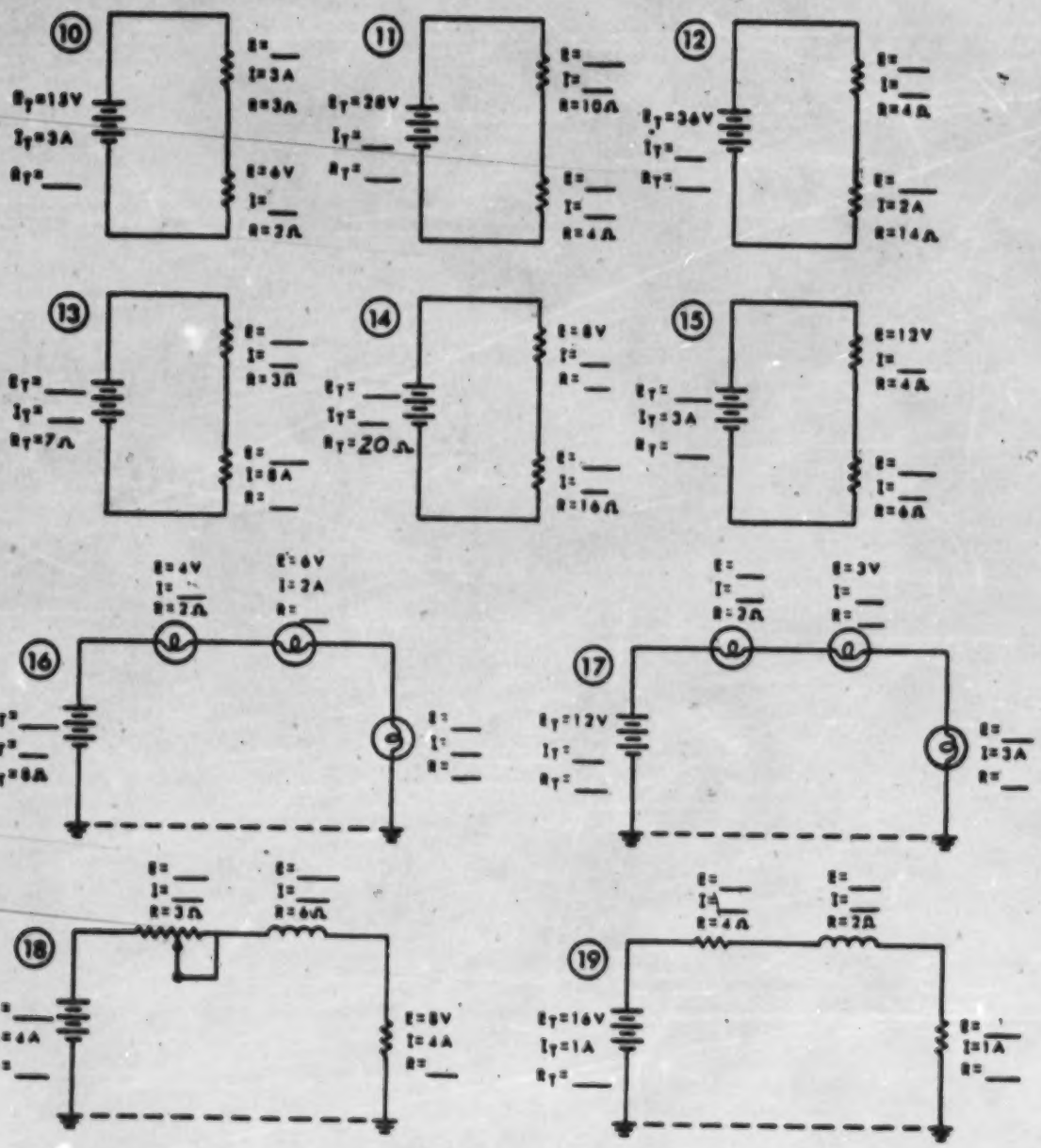
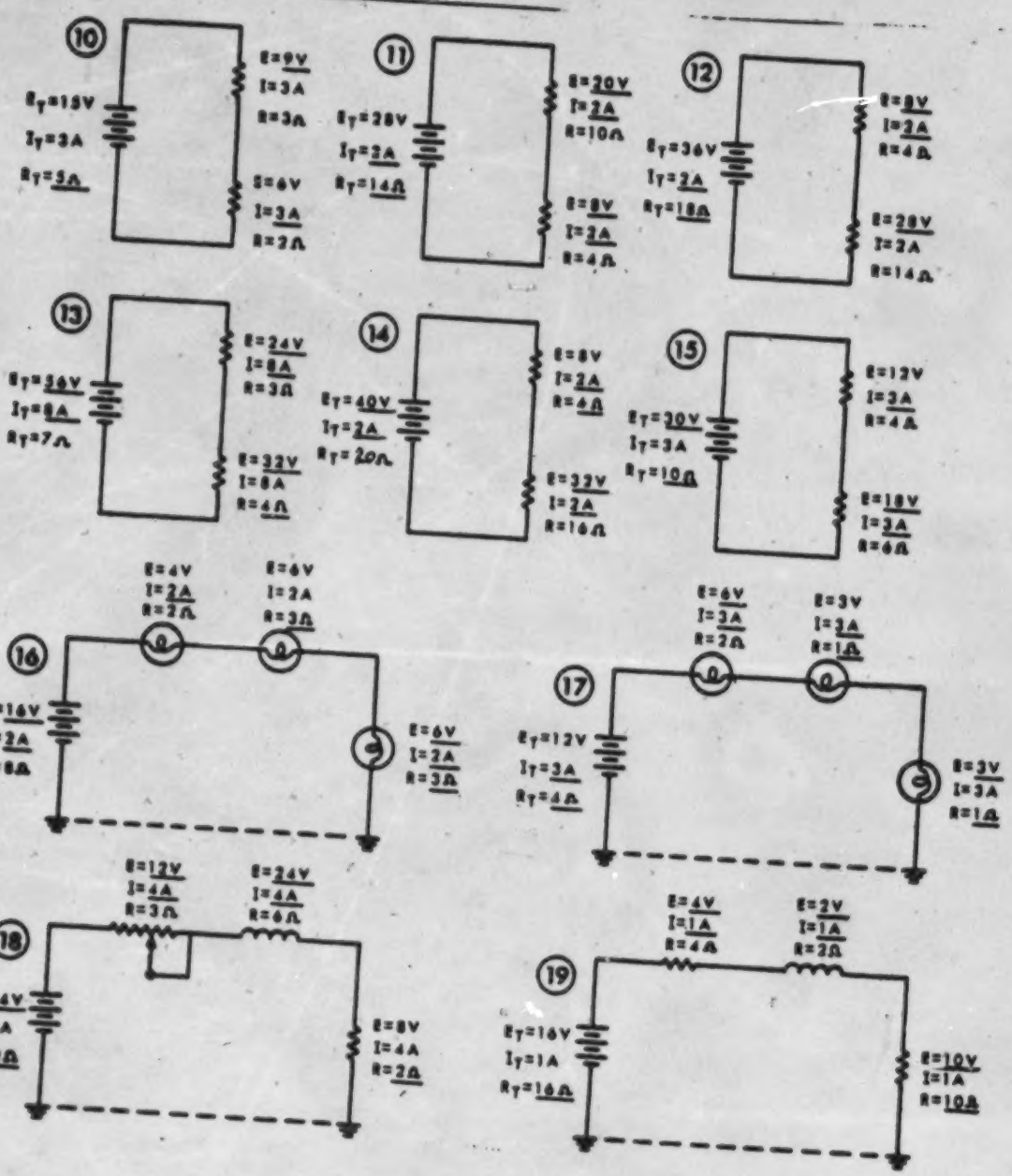
Frame 21

Use OHM'S LAW and the characteristics of a Series Circuit to solve the following Series Circuit problems. Write your answers in the spaces provided.



Answers to Frame 21:



Technical Training

Aircraft Environmental Systems Mechanic

SERIES CIRCUIT PERFORMANCE

1 February 1979

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Environmental Pneudraulics Branch
Chanute AFB, Illinois

3ABR42331-WB-117

SERIES CIRCUIT PERFORMANCE

OBJECTIVE

Using a DC fundamentals trainer, construct a series circuit and measure electrical values with one instructor assist allowed for each task area.

EQUIPMENT

	Basis of Issue
Trainer, P/N 521685 DC Fundamentals	1/student
Multimeter	1/student

SAFETY

Caution: Remove watches, rings, bracelets, etc., before starting any work on the equipment. It is also a good safety practice to work on the equipment with one hand. This practice reduces the chances of receiving an electrical shock to some vital body organ when working with electricity. Also remember that light bulbs, resistors, etc., do get HOT and could burn the skin.

PROCEDURE

Pay close attention to all directions that you are given in the workbook. When performing in the workbook, such as answering questions or recording electrical measurements if your response is incorrect, restudy the information with your instructor's assistance as needed. Do not hesitate to ask the instructor questions. You will be required to accomplish several exercises and have some of them checked by your instructor before you move to the next exercise. You will also find that many of the exercises have the correct answers on page 11. After you have completed all the exercises you will satisfactorily complete the progress check assigned by your instructor. Pages 15 through 22 may, if you wish, be removed for your convenience.

When you leave your trainer for scheduled or unscheduled breaks, complete the following checklist before you go.

1. Insure the SPST switch is turned OFF in the circuit.

2. Insure the 28V DC bus bar (red) has all the electrical leads removed from it.

3. Insure the negative (black) bus bar has all the electrical leads removed from it.

Supersedes 3ABR42231-WB-111, 26 August 1977.
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3370 TTGTC - 600; TTVSA - 1

4. Insure the multimeter is properly stored during this period.

a. Insure the controls on the meter are properly set for storage.

b. Leave the test leads attached to the meter.

c. Wrap the meter leads around the instrument.

d. Place the meter on the locker shelf.

5. When you return from the break take the same meter and go back to work.

Exercise 1

1. Trainer preparation for exercises 2 through 8.

a. The metal plate on the right side of the trainer may be raised for your workbook to lay on.

b. Sign out a multimeter, see the lab instructor if assistance is needed.

c. Insure that the instructor has connected power to the trainer. You will do this by measuring the power with the multimeter at the positive (red) and negative (black) bus bars. These bus bars are located in the lower right and left hand corners of the trainer. If you don't read a voltage (24V DC ± 4V DC) see your instructor.

d. Insure that fuse wire is across the fuse holders of each of the three (3) ammeters on the trainer. This will protect the ammeter internal circuit from over load. If the fuse wire is burnt in two or is missing, see your instructor for assistance.

e. Pull the circuit breaker out (open) and turn OFF (open) two (2) single pole single throw (SPST) switches.

f. Insure all leads in the draw are in good condition with a plug at both ends. If you find any damaged lead, give them to the instructor.

g. Examine the electrical leads ends, and note how you may connect them together if one lead is too short. See your instructor for assistance if needed.

Exercise 2

2. Build a series circuit with two (2) loads, one light bulb and one 10 ohm resistor as follows:

a. Using the electrical leads from the drawer, construct the circuit shown in figure 1, page 15, consisting of a circuit breaker, SPST switch, one light bulb, and one 10 ohm resistor.

Note: If an electrical lead is too short you may connect leads together to prevent stretching or breaking them.

b. Before applying power to your circuit, be sure you have only one path for current to flow from the negative to the positive source through the two loads. Tracing from negative (-) to positive (+) the electrons will first go through the 10 ohm resistor, then the lamp and on through the switch and circuit breaker to the positive (+) bus bar.

STOP and have your instructor check your work at this time.

c. After the instructor has checked the circuit and is present, you will do the following:

(1) Push in the circuit breaker.

(2) Turn the single pole single throw (SPST) switch ON. The lamp should light. If the lamp does not light, turn OFF the SPST switch and ask the instructor for assistance.

(3) If the lamp lights and everything appears OK, turn the SPST switch OFF.

STOP and have your instructor initial here before you proceed.

Note: The instructor must see that the circuit is properly constructed and also see an operational check performed. This must be done before the instructor initials above. You will not proceed until the instructor has initialed above.

Exercise 3

3. Using the ammeter in a series circuit.

a. Sometimes it is necessary to take amperage readings of a circuit. You are now going to learn how to set up and use the ammeter in a given series circuit. There are a few important facts that you must know about the ammeter before you proceed.

(1) Ammeters are connected in series with the rest of the series circuit. This means the ammeter will normally replace the wire in the circuit to be measured.

(2) With the ammeter connected there must be only one path for current to flow through the circuit, from negative to the positive bus bar. With the ammeter connected in the circuit or the part of a circuit being measured, all of the current to be measured in that circuit must flow through the meter. If any path (electrical wiring) allows current to bypass the meter the ammeter (current) reading will be incorrect.

(3) The ammeters must be protected by fuse wire on this trainer. If at any time the fuse wire burns in two or is missing, then without touching the circuit see your instructor for assistance.

b. Before continuing, answer the following questions.

(1) The ammeter is connected in _____ with the rest of the circuit.

(2) With ammeter connected there must be only _____ path for current to flow from the negative to the positive bus bar.

(3) The ammeters on the trainer are protected by _____ _____.

You will find the correct answers to the above questions on page 11 of this workbook. Do not check your work until you have answered all of the above questions. If you have any questions about the work thus far, see your lab instructor right NOW.

c. Refer to the circuits shown in figures 1 and 2. You will find these circuits are the same circuits. But in figure 2 you will also find that the ammeter (symbol) with leads has been added. Using the ammeter in the lower right hand corner of the trainer, you will be able to measure the amount of current flow in the circuit you have already constructed. You will accomplish this as follows:

(1) Take two electrical leads from the drawer and connect one to each side of the ammeter and let them hang as shown in figure 2.

(2) Be sure the circuit SPST switch is in the OFF position.

(3) Remember the ammeter has a positive (red) and negative (black) side, and it MUST NOT be wired into the series circuit backwards, or the ammeter could be damaged.

(4) Knowing that the ammeter must replace a circuit wire, the wire between points 1 and 2 will now be removed. See figure 3.

(5) The negative side of the ammeter must always be connected to the negative side of the circuit. So connect the ammeter negative lead to the negative bus bar. See figure 4.

(6) The positive side of the ammeter must always be connected to the positive side of the circuit. So connect the ammeter to point 2 of the circuit because it will be more positive than the negative bus bar when power is turned on. See figure 5.

Note: Now you have wired the ammeter in series in a series circuit to measure the total current flow in the series circuit with power on.

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(7) Turn ON the power (SPST) and record the ammeter reading in figure 5. If you DO NOT get a reading on the ammeter and/or circuit breaker pops, and/or fuse wire burns in two, turn OFF the SPST switch and see your instructor.

Note: Do not leave or turn the switch back on if you didn't get a reading the first time. This will help prevent internal damage to the ammeter. If you have problems with this exercise, see your instructor.

(8) Turn OFF the power (SPST).

Exercise 4

4. Measuring and proving current flow is the "SAME" in a series circuit.

a. You will use all three ammeters on the trainer to prove current flow is the "SAME" in a series circuit. One meter is already connected from exercise 3. If you do not have exercise 3 on the trainer, you must go back and place the circuit for exercise 3 in the trainer.

b. Use figure 5 (the exercise 3 circuit which you have already built) and the two other ammeters to complete this exercise. Figure 6 shows the wiring diagram to use. You are to change figure 5 by doing steps (1) through (3), then use the remaining steps to complete this exercise.

(1) Connect an ammeter between points 3 and 4. Remember the polarity of the (+) and (-) of the ammeter to the circuit. The positive lead of the ammeter will go to the most positive point and the negative ammeter lead will go to the most negative point of the circuit.

(2) Connect the other ammeter between points 5 and 6.

(3) Insure the ammeter polarity is correct, on all three ammeters. You should have all three ammeters in the circuit as shown in figure 6.

(4) Insure the circuit breaker is pushed in.

(5) Turn ON the power and record the ammeter readings in figure 6. If you do not get a reading on the ammeters and/or the circuit breaker pops, and/or fuse wire burns in two, turn OFF the power. Do not touch the circuit wiring and see your instructor. Do not leave or turn the switch back on if you didn't get a reading the first time. This could prevent internal damage to the ammeter.

(6) If your answers were correct, turn OFF the power to the circuit.

(7) If you have any questions, see your instructor NOW.

(8) If you have incorrect answers, see your instructor NOW.

(9) Put all the leads in the drawer if you fully understand this exercise.

You will find the correct answers to the above readings on page 11 of this workbook. Do not check your work until you have recorded all of the readings on figure 6.

Exercise 5

5. Series circuit with only one load, the light bulb.

a. In this exercise you will see the difference in amperage that was created by removing the one resistor from the circuit.

b. Build a series circuit like the one shown in figure 7. As you can see, one of the loads has been left out, the 10 ohm resistor.

c. Continue on to exercise 6.

Exercise 6

6. Measuring current flow in a series circuit with only one load the light bulb.

a. Using the three ammeters take amperage readings at the following check points in figure 8. Record these findings in figure 8.

b. Notice that the single lamp glows brighter than it did when you had the lamp and resistor in the circuit. WHY? Because the amperage increased in the circuit. WHY? Because you have removed or decreased the amount of resistance (opposition) in the circuit. Removing the resistor decreased the total resistance of the circuit. As a result the total amperage also increases. Remember, if we change any <u>one</u> of the three values of a circuit (voltage, amperage, or resistance) then the other two will be affected. The more resistance (ohms) you have in a given circuit the smaller the amperage. The lower the resistance in a circuit the higher the amperage will be if the voltage remains constant.

c. Referring to the one lamp circuit, figure 8, and on the trainer, answer the following questions.

1. The single lamp circuit has _____ (more/less) resistance to current flow than the two load circuit.

2. The single lamp glows brighter because the total current in the circuit has _____ (increased/decreased).

3. When the total resistance of a series circuit is decreased, the total amperage in the circuit _____ (increases/ decreases).

Note: Turn OFF the circuit power by opening the SPST switch and pulling out the circuit breaker, then remove all the leads and temporarily store them in the storage drawer.

You will find the correct answers to the above questions on page 11 of this workbook. Do not check your work until you have answered all of the above questions. If you have any questions about the work thus far, see your lab instructor right NOW.

Exercise 7

7. Construct a series circuit with two loads, one light bulb, one 10 ohm resistor, as follows:

a. Construct a series circuit as shown in figure 9.

b. Set up your multimeter to measure a maximum of 28V DC. STOP and have your instructor check your work and do not progress until the instructor has initialed here. _____

c. With the circuit breakers pushed in and the switch in the OFF position. Use the multimeter and take the following voltage readings and record them in figure 10 in the switch OFF column. Remember the following when using the multimeter:

(1) Be sure the multimeter is set up correctly before you take your measurements.

(2) Insure the multimeter red lead is placed on the positive side of the load, and the black lead placed on the negative side of the load in the circuit. See figure 10 multimeter leads.

(3) The multimeter when used for voltage readings IS NOT connected in series like an ammeter, BUT in parallel in the series circuit.

(a) Ammeter - Series (any kind of circuit).

(b) Voltmeter (multimeter) - parallel (any kind of circuit).

Note: Because the SPST switch, when in the OFF position has an air gap between its contacts, current <u>will not</u> flow through the switch or the circuit. You will read voltage across the switch in the OFF position. The reason for this will be explained later on in this exercise.

d. With the circuit breaker IN and switch ON use the multimeter to measure the following voltage readings and record them in figure 10 in the switch ON column.

e. Refer to checkpoint 6 and 7, figure 10.

(1) With the switch OFF, point 6 and 7 had a reading of approximately 28V DC. With the switch ON point 6 and 7 read zero (0) volts. WHY? Because the voltmeter reads a difference in potential (voltage). With the switch OFF the circuit is divided into a positive side and a distinct negative side. The voltmeter reads the difference between positive and negative of approximately 28V DC.

(2) When you closed the switch you noticed that the voltmeter dropped to a reading of zero (0) volts at points 6 and 7. By connecting 6 and 7 together, checkpoint 6 is just as positive as checkpoint 7. There is NO distinct difference between positive and negative now.

(3) But because the switch is closed you will find the TOTAL (sum) voltage drop across the two (2) loads is equal to the applied voltage at the bus bars or the voltage across the open switch.

f. Turn OFF the power to the circuit.

g. If you have any questions at this time, see your instructor NOW.

Exercise 8

8. Measuring voltage on a ground circuit.

a. Use the same circuit you constructed in figure 9 and do the following:

(1) Remove the ground wire between points 1 and 2. See figure 10.

(2) Take two leads from the drawer, connect one lead to point one and the other to points two. See figure 11.

(3) Connect the two wires lead ends together.

b. Turn on the power to the circuit (SPST switch).

c. Use the multimeter and measure between points 1 and 2, recording the readings in figure 12.

d. With the power still turned on, multimeter still connected to points 1 and 2, disconnect the circuit at the point where you hooked the two leads together. See figure 13.

(1) You will note the lamp goes out and the multimeter now reads about 28V DC. This is because you now have an open ground wire (circuit) between points 1 and 2.

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e. With the power still turned on, multimeter still connected to points 1 and 2, reconnect the two leads in the ground circuit.

(1) You will note the lamp comes on and the multimeter now reads 0V DC. This is because you now have a good circuit between points 1 and 2.

f. Remember a voltage reading on a ground wire (circuit) indicates an open ground, and a 0 zero reading on the ground wire (circuit) indicates a good ground. This is only with power applied to the circuit.

g. Remove all the leads and store them in the drawer and report to your instructor for a progress check assignment.

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Correct responses for exercises 1 through 8 and related figures.

EXERCISE 3

b. (1) series
(2) one
(3) fuse wire

c. (6) 1-2 __1__ amp (Figure 5) ±0.3 amps

EXERCISE 4

b. (5) 1-2 __1__ amp (Figure 6) ±0.3 amps
3-4 __1__ amp (Figure 6) ±0.3 amps
5-6 __1__ amp (Figure 6) ±0.3 anos

EXERCISE 6

a. (1) 1-2 __1.2__ amps (Figure 8) ±0.3 amps
3-4 __1.2__ amps (Figure 8) ±0.3 amps
5-6 __1.2__ amps (Figure 8) ±0.3 amps
TOTAL __1.2__ amps (Figure 8) ±0.3 amps

c. 1. less
2. increased
3. increased

EXERCISE 7

READINGS

1 & 2	0V	0V
2 & 3	0V	11V ± 3V DC
3 & 4	0V	0V
4 & 5	0V	15V ± 3V DC
5 & 6	0V	0V
6 & 7	26V ± 4V DC	0V
7 & 8	0V	0V
8 & 9	0V	0V
9 & 10	0V	0V

EXERCISE 8

c. 1 & 2 __0__ volts (Figure 12)

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PROGRESS CHECK INSTRUCTIONS

This progress check will require you to correctly construct a series circuit and measure electrical values with one instructor assist allowed for each task area. Instructor assist for each task area is defined as an aid, such as technical direction or explanation given a student, who can proceed no further on his/her own. The instructor will initial your work after you satisfactorily completed each task of the progress check. If you do not pass the progress check you will follow the instructions given by the instructor.

You will not communicate (talk, etc) with other students during the progress check without your lab instructor's permission.

You will not use fellow student's work to solve the problems in this progress check.

You must satisfactorily complete this progress check before further progression to other lab progress checks.

Have your instructor select and initial on page 12 or 13 the series circuit progress check you are to draw on figure 14. Using a lead pencil only, draw in the series circuit leads between the various symbols. Later you will construct this circuit on the trainer. After you have satisfactorily completed the progress check, you will follow the instructions on page 14.

_____ Instructor's initials. Assigned progress check #1.

After completion of each task listed below, do not progress until the instructor has initialed your work for that task.

TASK 1 Draw the series circuit for three light bulbs, SPST switch, and circuit breaker on figure 14.

_____ Instructor's initials. Task initials _____ _____.

TASK 2 Construct the series circuit drawn on figure 14 on the trainer and complete an operational check for the instructor.

_____ Instructor's initials. Task initials _____ _____.

TASK 3 Measure and record the electrical values required below.

Total current flow _____ amps.

Total voltage to the circuit _____.

Voltage drop across each bulb _____. (left)

_____. (center)

_____. (right)

_____ Instructor's initials. Task initials _____ _____.

Turn to page 14 for further instructions.

Note: If the instructor provides an instructor assist for a task, the instructor will initial behind task initials (see objective).

_____ Instructor's initials. Assigned progress check #2.

After completion of each task listed below, do not progress until the instructor has initialed your work for that task.

TASK 1 Draw the series circuit for three 10 ohm resistors, SPST switch, and circuit breaker on figure 14.

_____ Instructor's initials. Task initials _____ _____.

TASK 2 Construct the series circuit drawn on figure 14 on the trainer and complete an operational check for the instructor.

_____ Instructor's initials. Task initials _____ _____.

TASK 3 Measure and record the electrical values required below.

Total current flow _____ amps.

Total voltage to the circuit _____ volts

Voltage drop across each resistor _____ (left)

_____ (center)

_____ (right)

_____ Instructor's initials. Task initials _____ _____.

Turn to page 14 for further instructions.

Note: If the instructor provides an instructor assist for a task, the instructor will initial behind task initials (see objective).

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After you have satisfactorily completed the progress check, you will do the following:

1. Put all the good leads in the drawer of the trainer.

2. Give all the broken leads to the lab instructor with the parts.

3. Place the work table in the down position on the trainer.

4. Return the multimeter to its storage cabinet. Be sure the controls on the meter are set correctly for storage.

5. You will turn in your work to the lab instructor before you leave the lab area.

Note: You may review any part or all of this workbook if you wish, but your work will not leave the lab area without the lab instructor's permission.

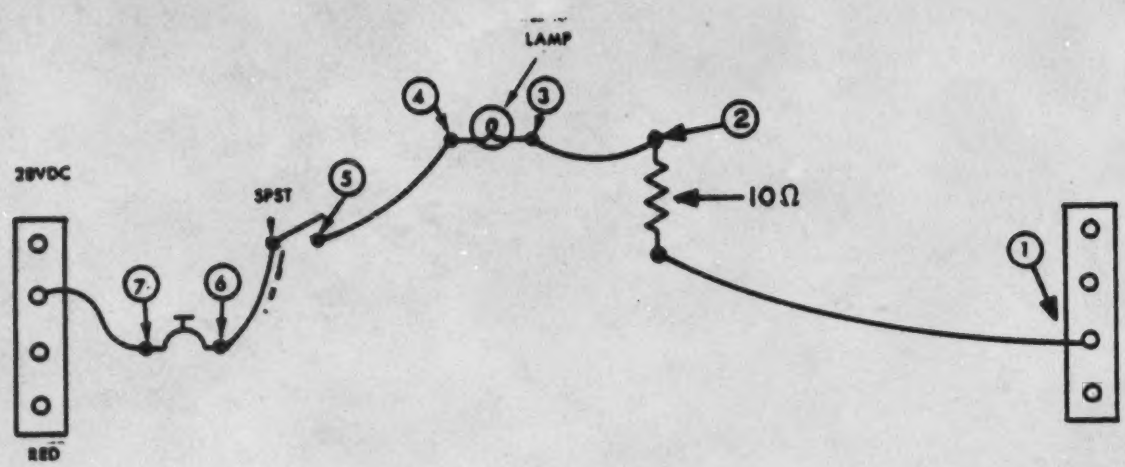

Figure 1.

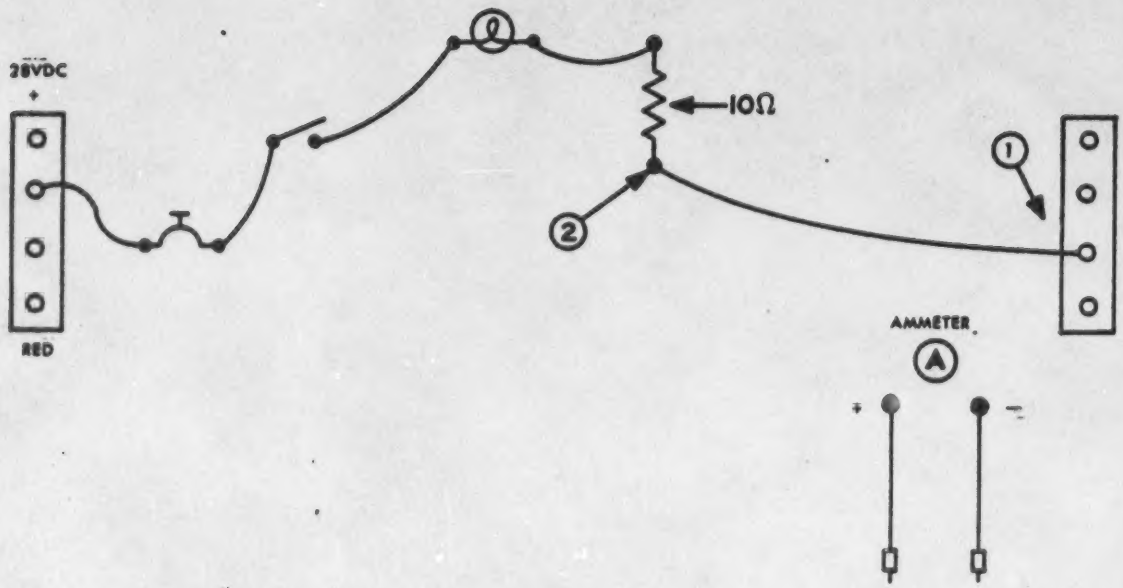

Figure 2.

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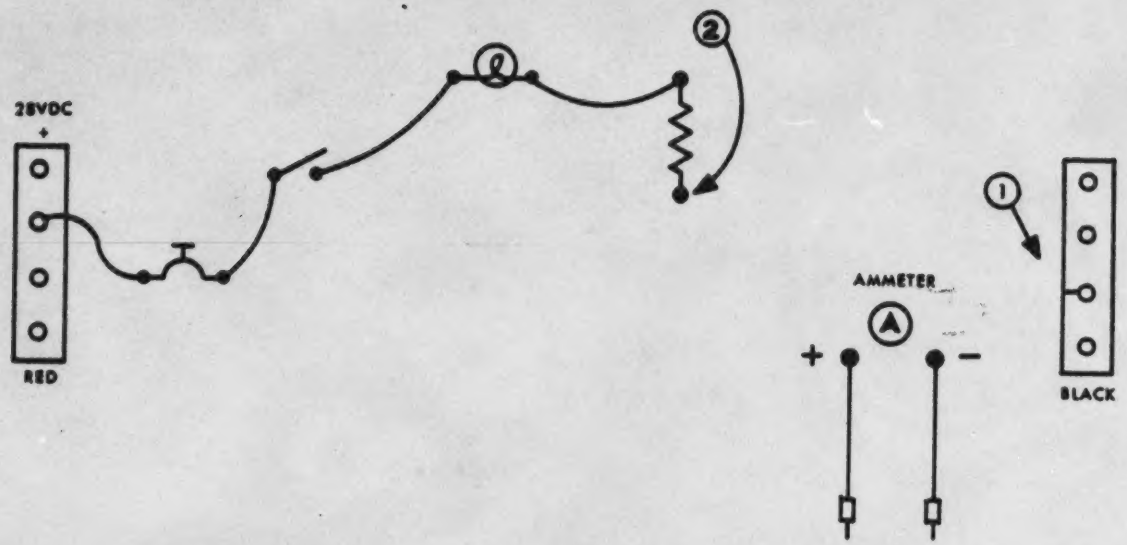

Figure 3.

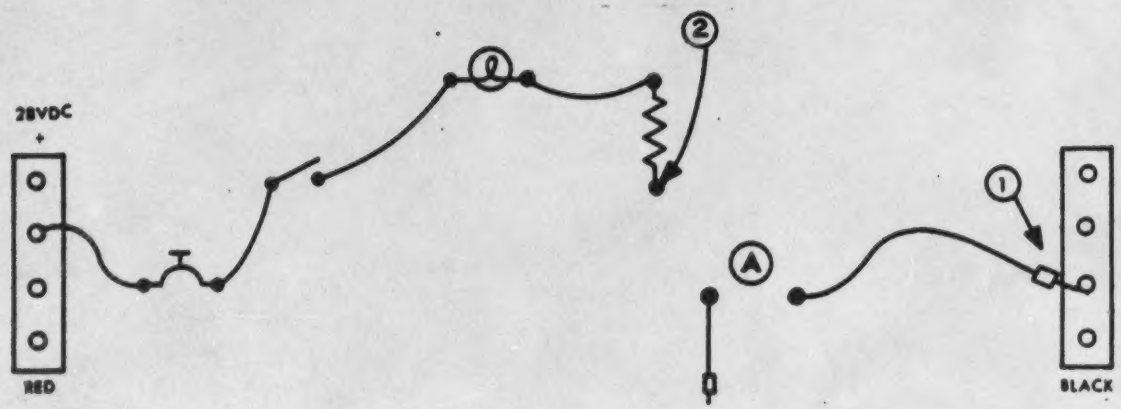

Figure 4.

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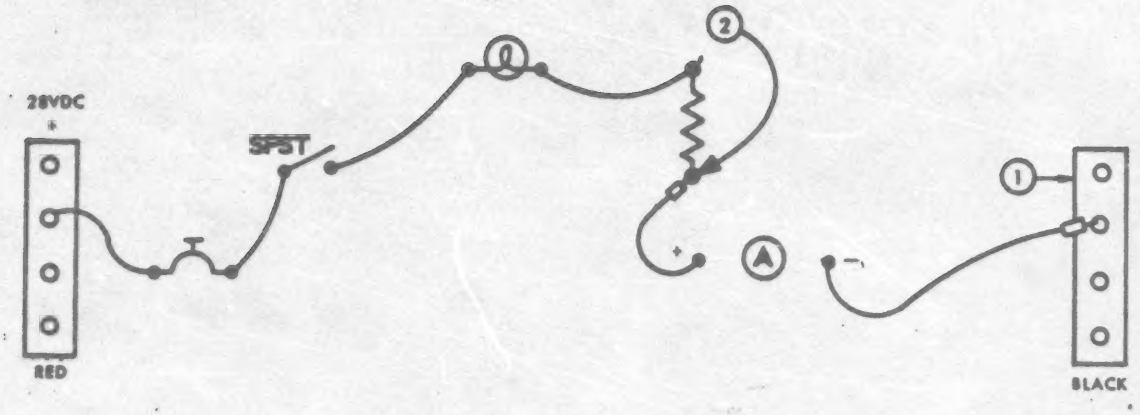

Figure 5.

CHECKPOINT	AMPERAGE READING
1-2	_____ amps

See page 11 for correct answers.

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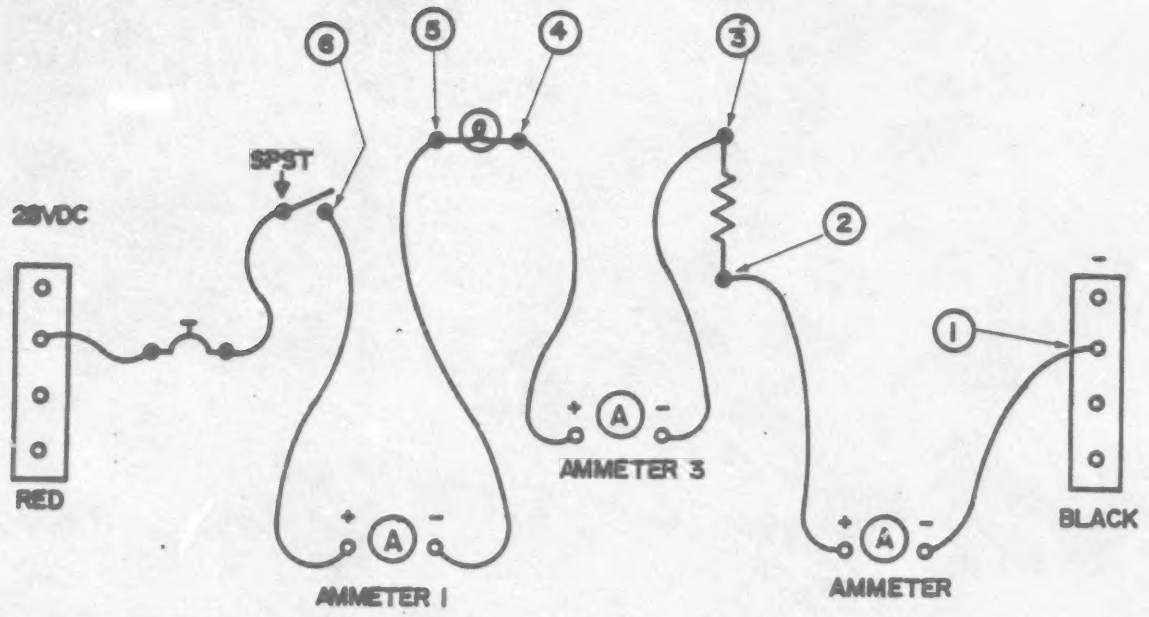

Figure 6.

CHECKPOINT	AMPERAGE READING
1-2	_____ amps
3-4	_____ amps
5-6	_____ amps

See page 11 for correct answers.

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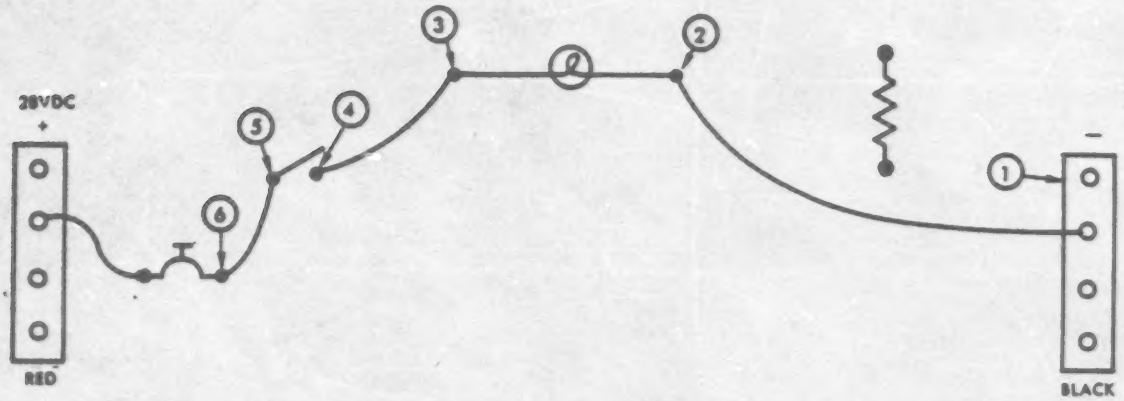

Figure 7.

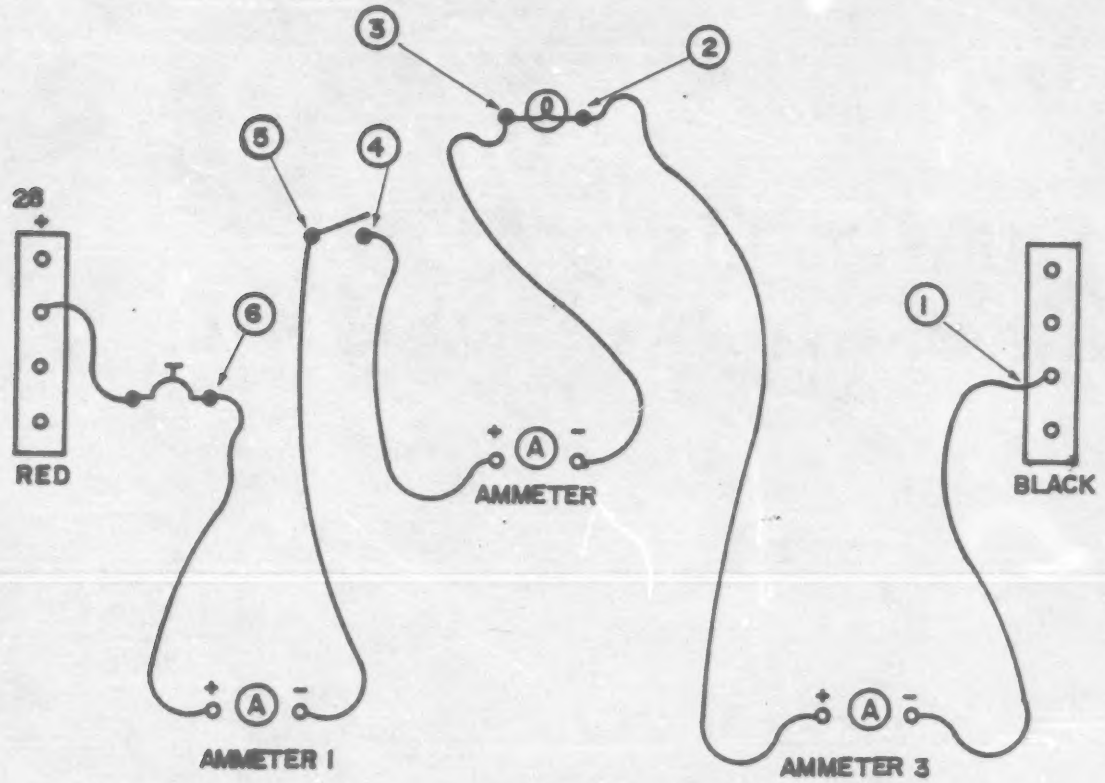

Figure 8.

CHECKPOINTS	AMPERAGE READINGS
1 & 2	_____ amps
3 & 4	_____ amps
5 & 6	_____ amps
Total current	_____ amps

See page 11 for correct answers.

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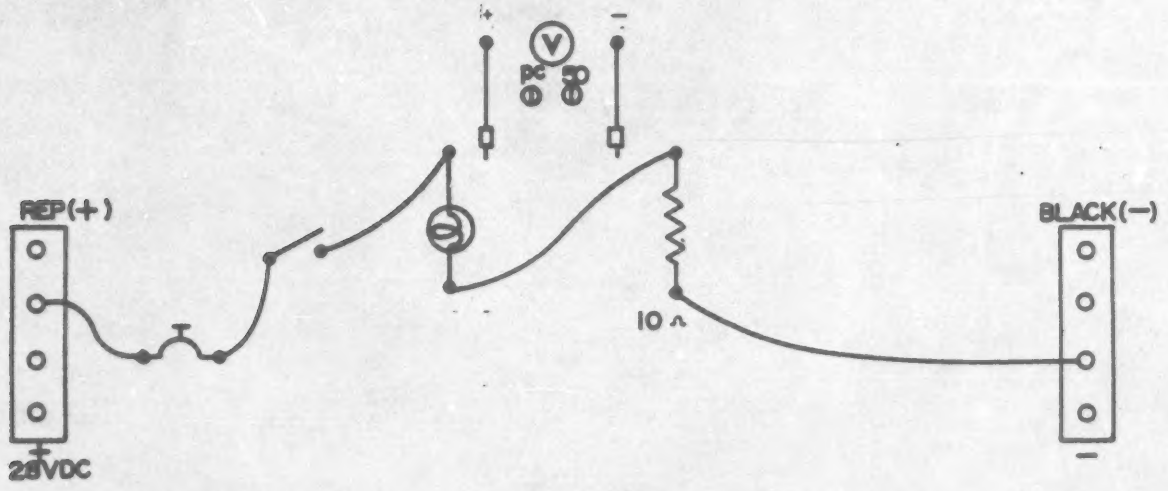

Figure 9.

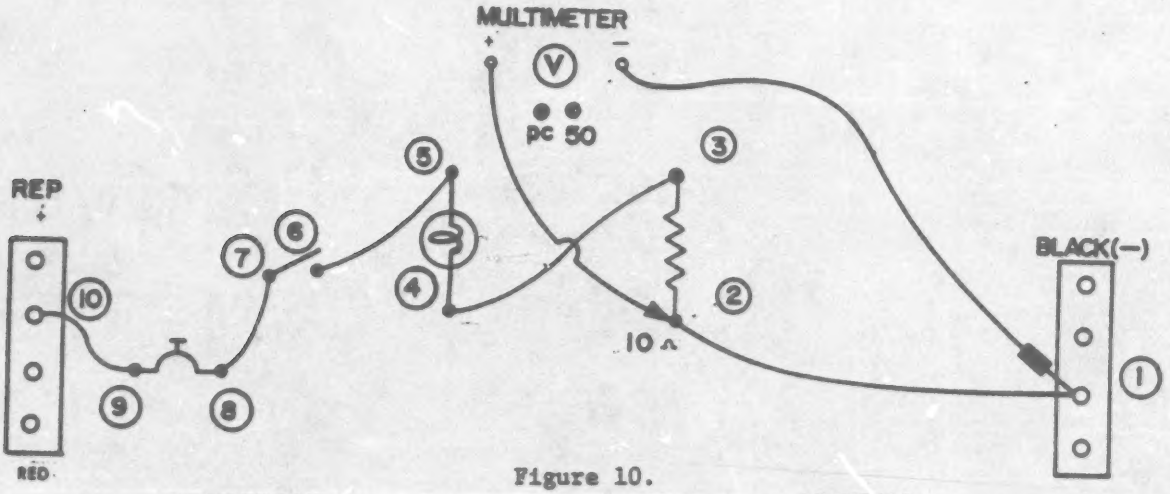

Figure 10.

CHECKPOINTS

READINGS
SW. OFF SW. ON

(-) 1 & 2 (+) _____ _____
(-) 2 & 3 (+) _____ _____
(-) 3 & 4 (+) _____ _____
(-) 4 & 5 (+) _____ _____
(-) 5 & 6 (+) _____ _____
(-) 6 & 7 (+) _____ _____
(-) 7 & 8 (+) _____ _____
(-) 8 & 9 (+) _____ _____
(-) 9 & 10 (+) _____ _____

See page 11 for correct answers.

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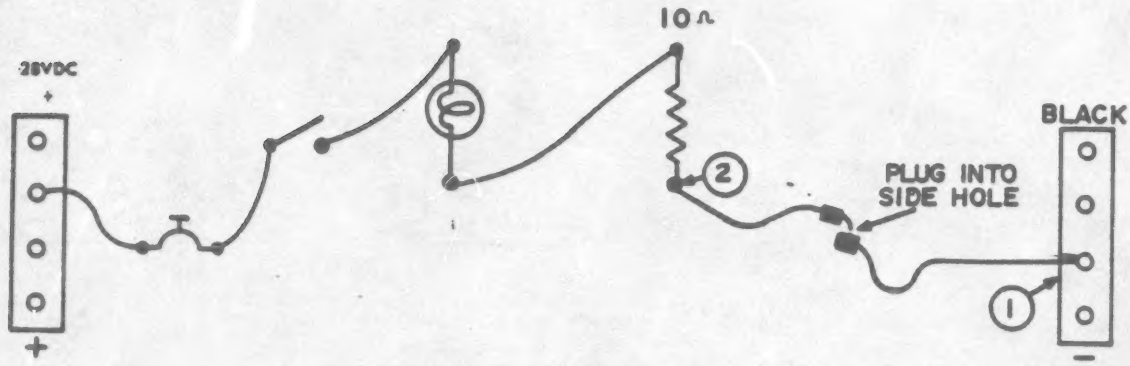

Figure 11.

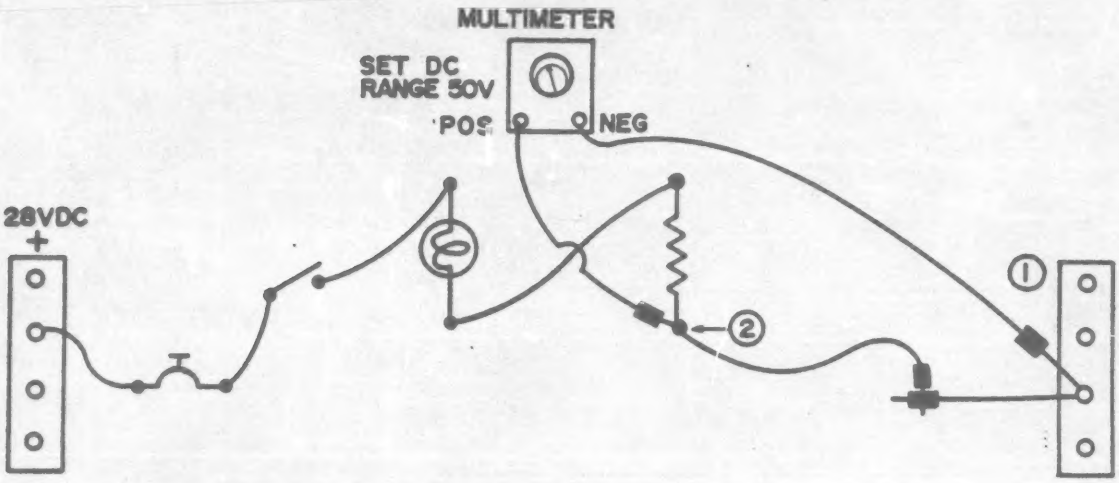

Figure 12.

CHECKPOINTS	READINGS SW. ON
1 & 2	_____V DC

See page 11 for correct answers.

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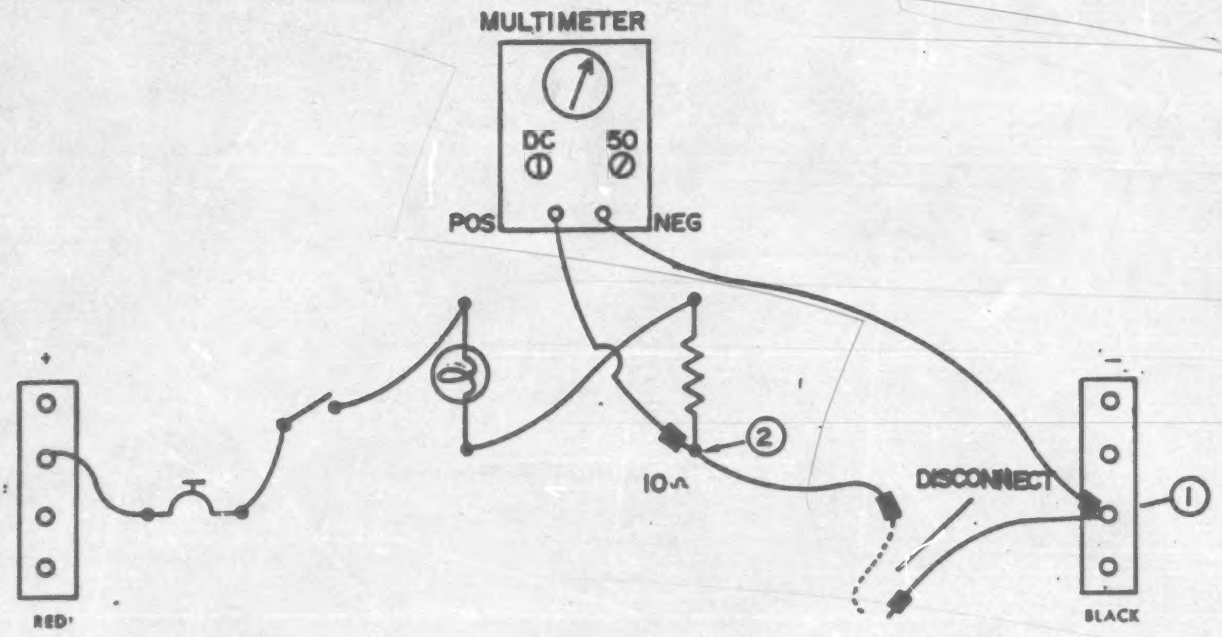

Figure 13.

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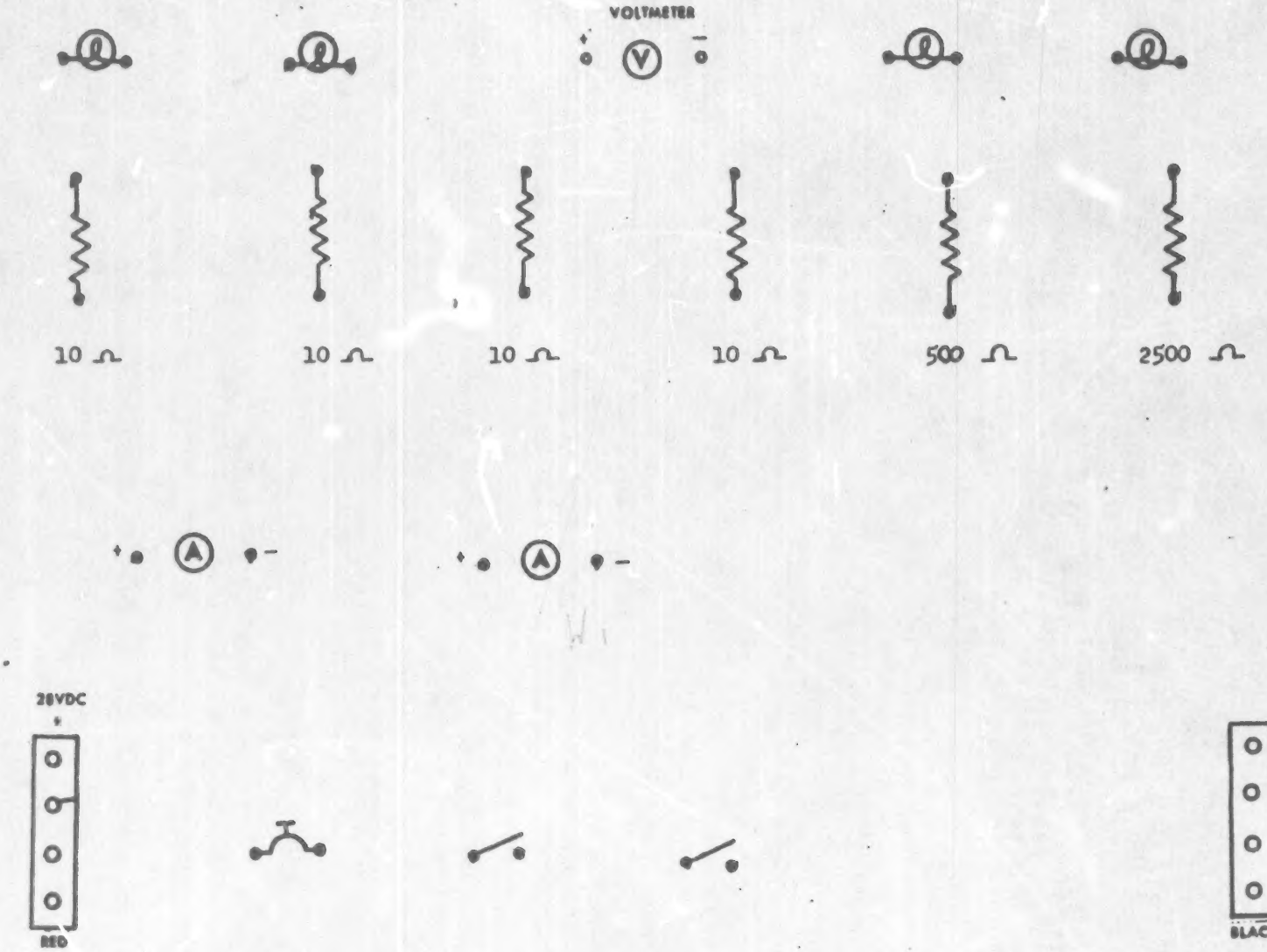

Figure 14.

PROGRAMMED TEXT
ABR42331-PT-118

Technical Training

Aircraft Environmental Systems Mechanic

PARALLEL CIRCUITS

11 November 1977

3350 TECHNICAL TRAINING WING
3370 Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE
DO NOT USE ON THE JOB

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FOREWORD

This programmed text was prepared for use in Course 3ABR42331, Aircraft Environmental System Mechanic. The material contained herein has been validated with 30 students from the subject course. Ninety percent of the student tested achieved or surpassed the criteria established in the lesson objectives. Average time to complete this PT was 50 minutes.

OBJECTIVES

1. Use Kirchhoff's current law to solve for unknown values in basic electrical circuits.

2. Use Kirchhoff's voltage law to solve for unknown values in basic electrical circuits.

3. Use Ohm's law and power formulas to solve for unknown values in basic electrical circuits.

Standard of Performance:

A minimum of 8 out of the 10 unknown values must be correct.

INSTRUCTIONS

This programmed text presents information in small steps called frames. Carefully study the written material and/or schematic in each frame until you are satisfied you understand its contents. Each frame requires you to select true statements, solve problems, etc. Specific instructions are provided in each frame. After you have made your response on the response sheet, compare your answer with the answer on the top of the next frame.

If you are correct, go on to the next frame. If you are incorrect, study the frame again and correct your mistakes before continuing. If you still can't understand your mistakes, ask your instructor for assistance. Read carefully, select the correct answer(s) and DO NOT HURRY. DO NOT MARK IN THIS TEXT. Be sure you have the handout (HO) in front of you called RULES, LAWS AND FORMULAS.

Supersedes 3ABR42231-PT-114A, 26 July 1971.
OPR: 3370 TTG
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3370 TTGTC - 300; TTVSR - 1 2

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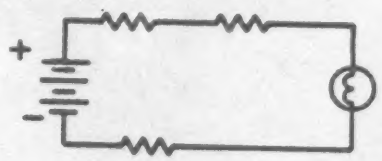
Frame 1

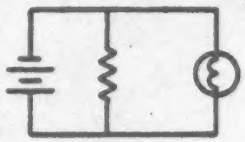
A parallel circuit is a circuit that has <u>two or more paths</u> for current to flow through. The components that make up a parallel circuit are arranged so that current will have more than one way to flow. <u>Start</u> tracing at the <u>negative pole of the power source</u> and follow all the paths back to the positive circuit.

Which circuit(s) below is/are PARALLEL CIRCUIT(s) and write their number(s) on the response sheet.

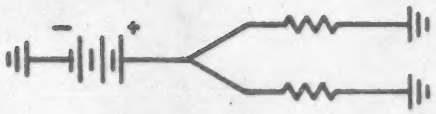
1.



2.



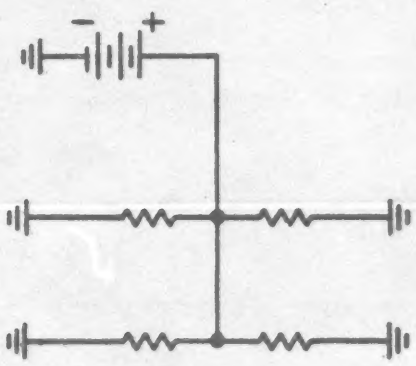
3.



4.

5.

6.



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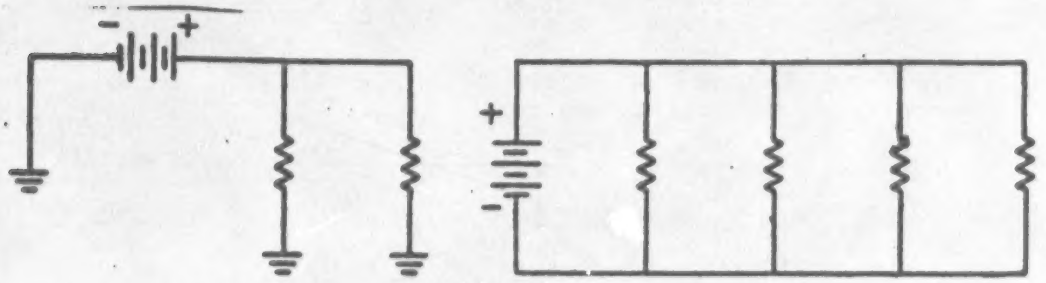
Answers to Frame 1: 2, 3, 6

Frame 2

The illustrations below are parallel circuit diagrams.



Which statement correctly describes parallel circuits? Write your answer on the response sheet.

1. Circuit components are arranged such, that all the current must flow through the only path provided.

2. Current will divide and flow through all of the paths provided.

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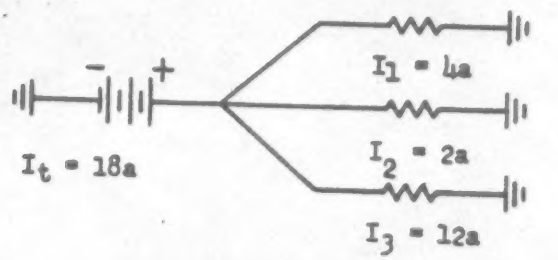
Answer to Frame 2: 2

Frame 3

Since current has been provided with more than one path in which to flow, you can see how the main current would divide and flow across each of the paths. How much of the current flows through each branch of the circuit depends on how much resistance is in each branch. Certainly there will be more current flowing in a branch that has a small resistance than there will be in a branch with a large amount of resistance. Regardless of the amount of current flowing across each branch, one thing is certain, the "TOTAL current flow in the entire parallel circuit is the SUM of the currents flowing through each branch!"



Write the letter of a statement below that describes the characteristic of amperage in a parallel circuit on the response sheet.

A. Total amperage is the sum of all the amperages of the branches.

B. Total amperage is the same throughout the entire circuit.

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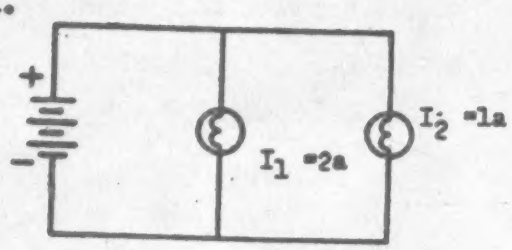
Answer to Frame 3: A

Frame 4

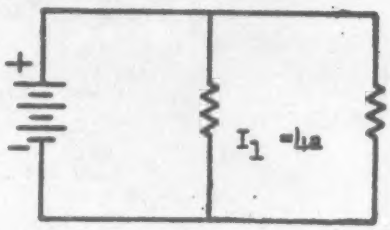
If you recognize total amperage as being the SUM of the amperages throughout the circuit, solve the problems below. Enter your answer in the proper space on the response sheet.

1.



I_t = _____

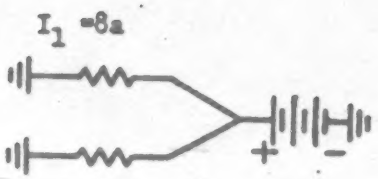
2.



I_2 = _____

I_t = 9a

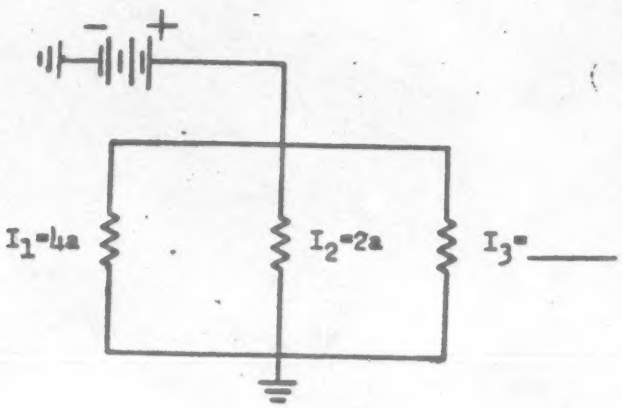
3.



I_2 =3a

I_t = _____

4.



I_t = 100a

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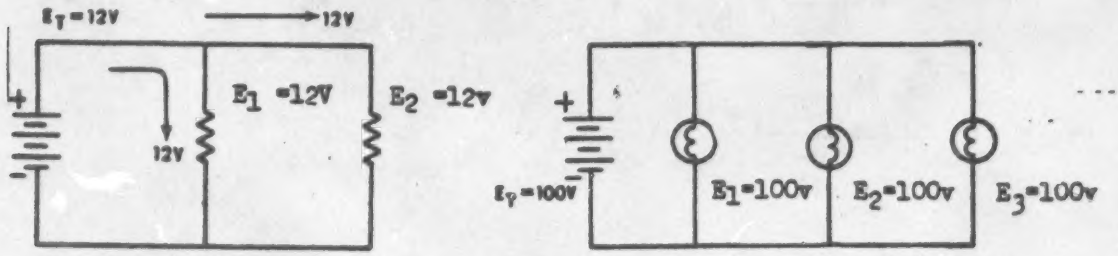
Answers to Frame 4: 1. 3a 2. 5a 3. 11a 4. 94a

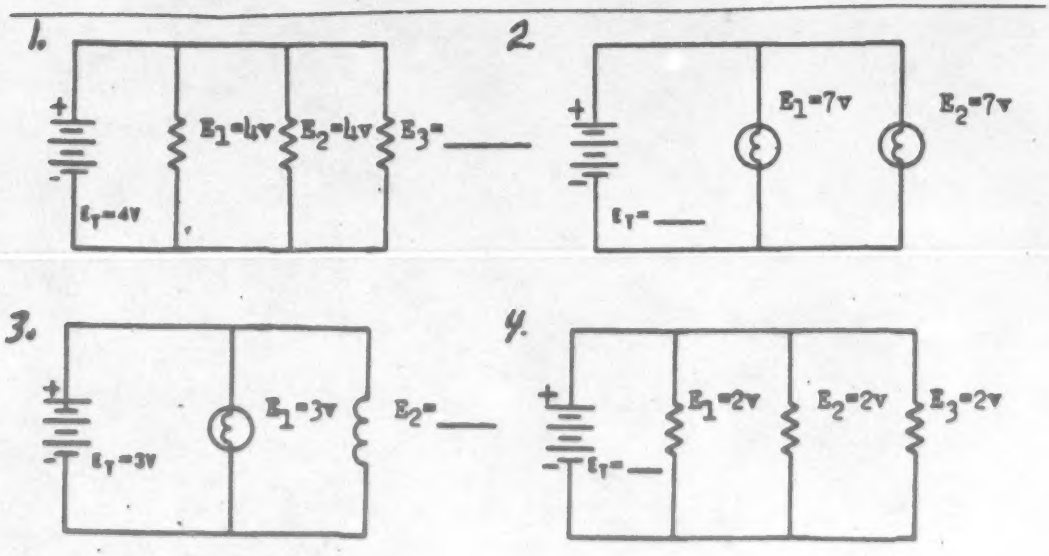
Frame 5

Total amperage is ALWAYS the SUM of the amperages in a parallel circuit. Let's consider the effect of voltage in a parallel circuit. Voltage in a parallel circuit pushes with equal pressure across all of the branches. Thus, what we have said here is: Voltage is the SAME across each path in the circuit.

Notice what happens to the applied voltage in the diagrams below.



Below are some parallel problems. Solve the problems and write your answers in the spaces provided on the response sheet.

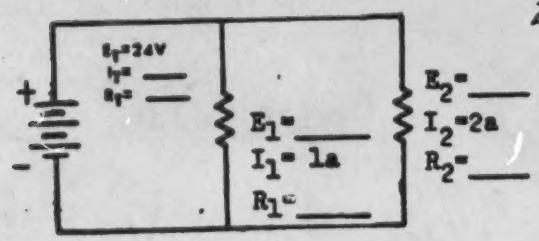


Answers to Frame 5: 1. 4V 2. 7V 3. 3V 4. 2V

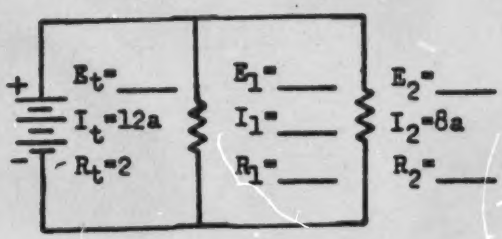
Frame 6

So far you have seen that amperage is the "SUM" and voltage is the "SAME" in a parallel circuit. Using this information and OHM'S law, solve the problems listed below and write your answers in the spaces provided on the response sheet.

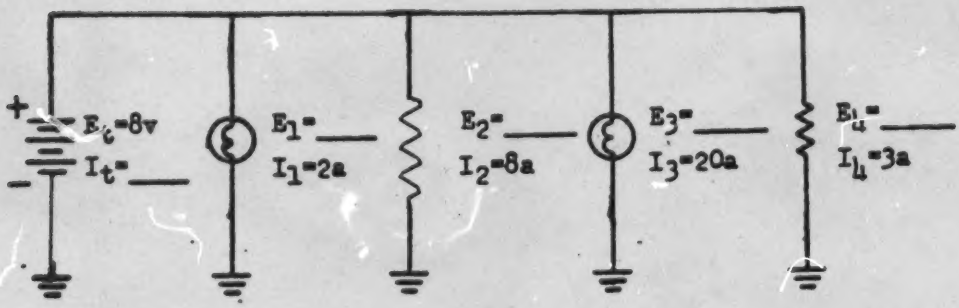
1.



2.



3.



Answers to Frame 6:

1.	E_t = 24V	E_1 = 24	E_2 = 24		
	I_t = 3a	I_1 = 1a	I_2 = 2a		
	R_t = 8Ω	R_1 = 24Ω	R_2 = 12Ω		
2.	E_t = 24V	E_1 = 24V	E_2 = 24V		
	I_t = 12a	I_1 = 4a	I_2 = 8a		
	R_t = 2Ω	R_1 = 6Ω	R_2 = 3Ω		
3.	E_t = 8V	E_1 = 8V	E_2 = 8V	E_3 = 8V	E_4 = 8V
	I_t = 33a	I_1 = 2a	I_2 = 8a	I_3 = 20a	I_4 = 3a

Frame 7

Perhaps you noticed while you were working the problems in frame 6, that the total resistance (R_t) was even less than the smallest resistor in the circuit! If you didn't notice, go back and look at the R_t value. How can this be? By adding more resistors in parallel, the current has more paths to flow through. Therefore, the total resistance in the circuit must be lowered to allow more current flow from negative to positive.

Which statement below best describes resistance in a parallel circuit? Write your answer on the response sheet.

1. Adding resistors in parallel will cause resistance to increase and amperage to decrease.

2. Adding resistors in parallel decreases the resistance by offering more paths for current to flow, therefore, increasing the amperage.

3. Total resistance is the sum of the resistors in parallel.

4. Total resistance is the same as any resistor in the circuit.

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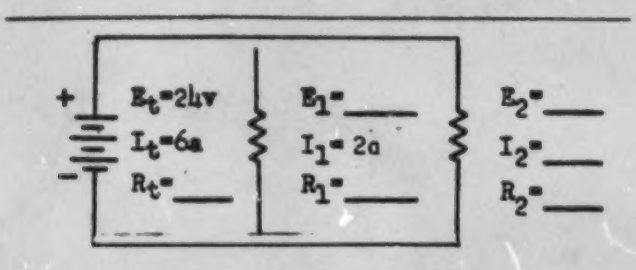
Answer to Frame 7: 2

Frame 8

Using Ohm's Law and the characteristics of voltage (same) and amperage (sum), solve this problem. Pay particular attention to the total resistance. Write your answer in the spaces provided on the response sheet.



Before you compare your answer with the ones on the next page, did you find the total resistance (R_t) to be less than the smallest resistor? If not, work the problem again.

Answers to Frame 8:

E_t = 24V	E_1 = 24V	E_2 = 24V
I_t = 6a	I_1 = 2a	I_2 = 4a
R_t = 4Ω	R_1 = 12Ω	R_2 = 6Ω

Frame 9

Match the terms to the statements on the left by writing the letter of the terms on the right in the appropriate space provided.

_____1. Remains the SAME throughout the parallel circuit.

_____2. Is the SUM of all of those in the parallel circuit.

_____3. Is SMALLER than the smallest in the parallel circuit.

a. Current

b. Voltage

c. Total resistance (R_t)

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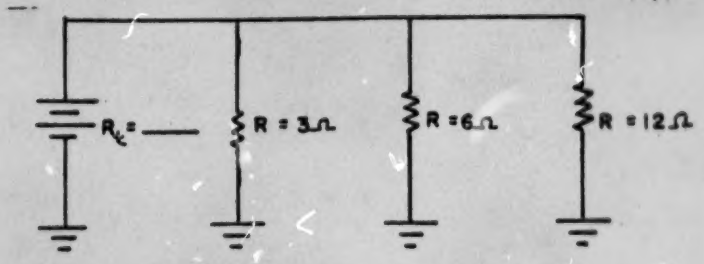
Answers to Frame 9: 1. b 2. a 3. c

Frame 10

How to mathematically solve for the total resistance in the parallel circuit without current or voltage values given in a circuit is shown below. What is the total resistance? It can't be 21 ohms since that isn't "smaller than the smallest resistor."

Using the formula shown you will be able to solve for any R_t in a parallel circuit. This is called a reciprocal formula. You should use scratch paper to work this problem below as you study it.



$$R_t = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \text{etc.}}$$

Now let's take only what's needed from this formula and solve for R_t in the above circuit.

$$R_t = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Because the circuit has only three resistors we will need only part of the formula to solve R_t for the above circuit.

$$R_t = \frac{1}{\frac{1}{3\Omega} + \frac{1}{6\Omega} + \frac{1}{12\Omega}}$$

Now substitute the resistive values into the formula.

$$R_t = \frac{1}{\frac{1}{3\Omega} + \frac{1}{6\Omega} + \frac{1}{12\Omega}} \leftarrow \text{numerator} \leftarrow \text{denominator}$$

In any fraction the top number is called the numerator and the bottom number is the denominator. The lowest common denominator (LCD) is the smallest number which all denominators can be divided into evenly. In our example 12 is the LCD, (the smallest number 3, 6, and 12 can be divided into evenly).

(LCD) $12 \div 3\Omega = 4$
$12 \div 6\Omega = 2$
$12 \div 12\Omega = 1$

12

Frame 10 (Continued)

Replace the resistive values with equal fractions which use the LCD as their denominators. To do this, divide the denominator of each fraction (3Ω, 6Ω, and 12Ω) into the LCD and enter the result over the LCD.

$$R_t = \frac{1}{\frac{?}{12} + \frac{?}{12} + \frac{?}{12}}$$

$$\frac{1}{3\Omega} = \frac{?}{12} = 3\overline{)12}^{\,4} = \left(\frac{4}{12}\right)$$

$$\frac{1}{6\Omega} = \frac{?}{12} = 6\overline{)12}^{\,2} = \left(\frac{2}{12}\right)$$

$$\frac{1}{12\Omega} = \frac{?}{12} = 12\overline{)12}^{\,1} = \left(\frac{1}{12}\right)$$

$$R_t = \frac{1}{\frac{4}{12} + \frac{2}{12} + \frac{1}{12}}$$

Now, add the numerators, 4 + 2 + 1 = 7. DO NOT add the LCD, simply enter the sum of the numerators over the LCD (12).

$$R_t = \frac{1}{\frac{4 + 2 + 1}{12}}$$

$$R_t = \frac{1}{\frac{7}{12}}$$

To complete the problem you need to divide $\frac{7}{12}$ into 1 ($\frac{7}{12}$ is actually the denominator of the larger fraction and 1 is the numerator). Dividing a fraction into another number is the same as inverting that fraction and multiplying it times the other number.

$$R_t = 1 \div \frac{7}{12}$$

$$R_t = 1 \times \frac{12}{7}$$

$$R_t = \frac{12}{7}$$

The final step is to convert this fraction into a whole number. Do this by dividing the denominator into the numerator.

$$R_t = 7\overline{)12.00}^{\,1.71}$$

$$\begin{array}{r} 7 \\ \hline 50 \\ 49 \\ \hline 10 \\ 7 \\ \hline \end{array}$$

$$R_t = 1.71\Omega$$

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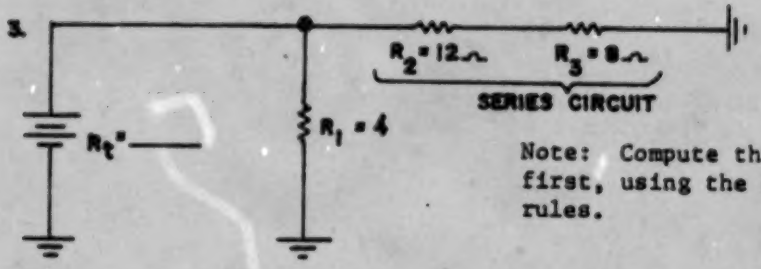
Frame 10 (Continued)

Using the reciprocal formula solve for R_t in the circuits below. Write your answers on the response sheet.

1.

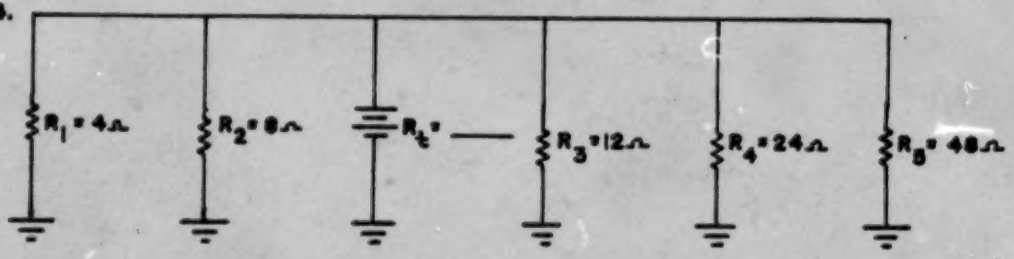
2.

3.



Note: Compute the series circuit first, using the series circuit rules.

4.



Answers to Frame 10: 1. 1.8Ω 2. 2.09Ω 3. 3.33Ω 4. 1.92Ω

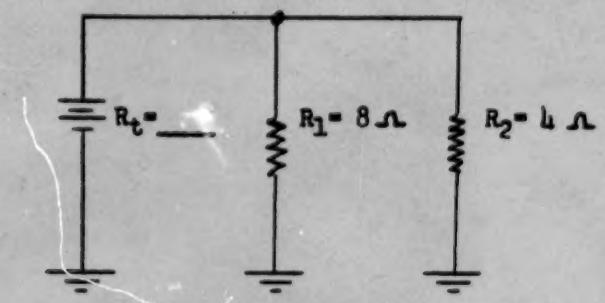
Frame 11

The next formula we will cover is the product over the sum, which is also used to solve for total resistance in a parallel circuit. This formula is primarily used when there are two (2) resistors in parallel whether they are of equal value or not.

When two (2) numbers are multiplied the answer is called a product. When two (2) numbers are added the answer is a sum. Therefore this formula is worked by multiplying two (2) numbers, then adding the same two (2) numbers, and dividing the two (2) answers.

For the circuit shown below, we will solve for R_t using the product over the sum formula. The formula you just covered in the last frame could also be used, however, at this time let's use the product over the sum.

You should use scratch paper to work this problem below as you study it.



Step (1) $R_t = \frac{R_1 \times R_2}{R_1 + R_2}$

(2) $R_t = \frac{8 \times 4}{8 + 4} = \frac{32}{12}$

(3) $R_t = \frac{32}{12} = 2.666\Omega$

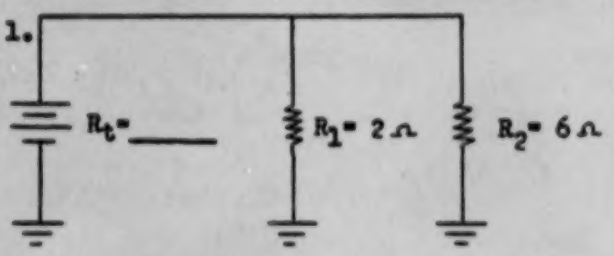
(4) $R_t = 2.666\Omega$

(5) $R_t = 2.67\Omega$

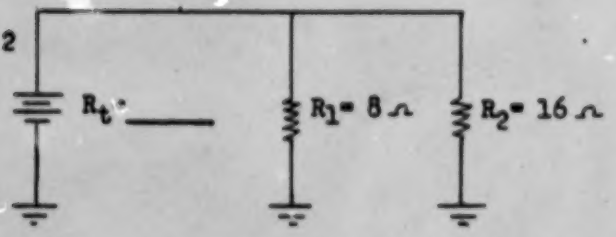
Frame 11 (Continued)

Using the product over the sum formula solve for R_t in the circuit below. Write your answer(s) on the response sheet.

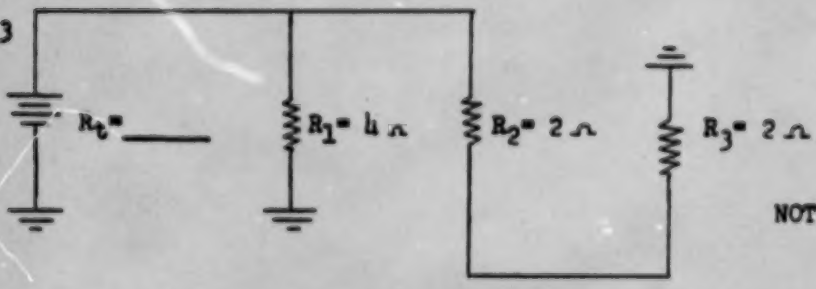
1.



2

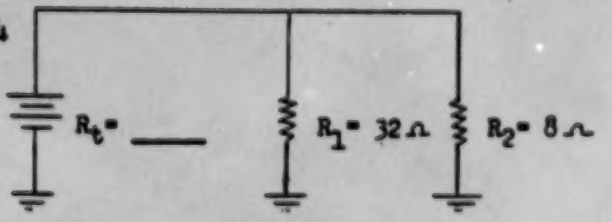


3



NOTE: Compute the total resistance in the series circuit.

4



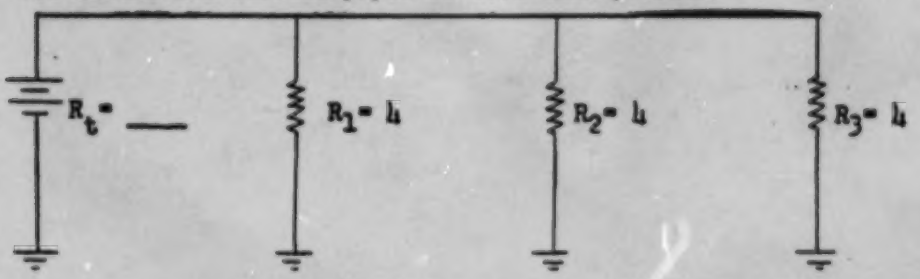
Answers to Frame 11: 1. 1.5Ω 2. 5.33Ω 3. 2.0Ω 4. 6.4Ω

Frame 12

The last formula we will cover is the resistive value over the total amount of like resistors in parallel.

This formula is primarily used to solve for total resistance in parallel circuit if all the resistance values in parallel are equal. The reciprocal formula shown in frame 10 can also be used, however the formula, shown in use below, is easier and faster to use if the resistive values are equal in value.

You should use scratch paper to work this problem.



Step (1) $R_t = \frac{R}{N}$ — The value of one of the resistors in parallel if they are all equal in value. The number of resistors in parallel.

(2) $R_t = \frac{4\Omega}{3 \text{ ea}}$ — This 4Ω resistance is the value of one of the 4Ω resistors in parallel only if all the resistors in the circuit are of equal value. This is the total of like resistors used in parallel with each other.

(3) $R_t = \frac{4\Omega}{3 \text{ ea}} = 1.333$

(4) $R_t = 1.333 = 1.33\Omega$

(5) $R_t = 1.33\Omega$

$$3\overline{)4.000}\quad 1.333$$

$\frac{3}{10}$

$\frac{9}{10}$

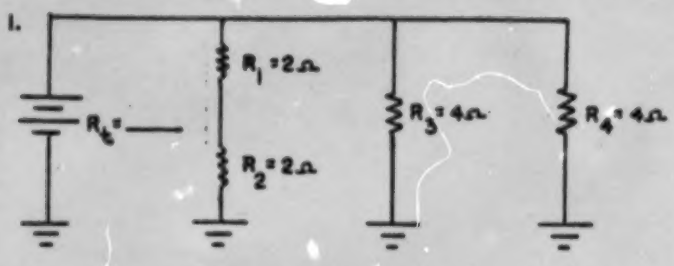
$\frac{9}{10}$

$\frac{9}{1}$

Frame 12 (Continued)

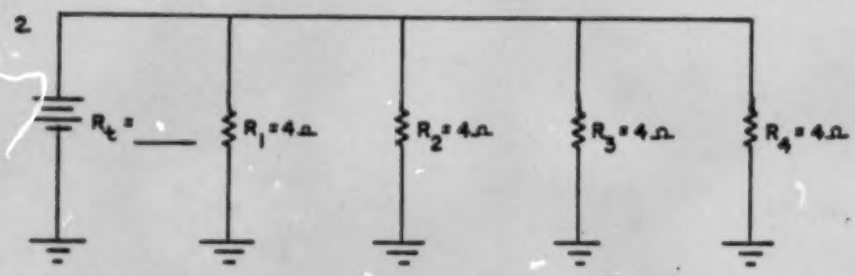
Using the resistive value over the number of like resistors formula solve for R_t in the circuit below. Write your answer(s) on the response sheet.

1.

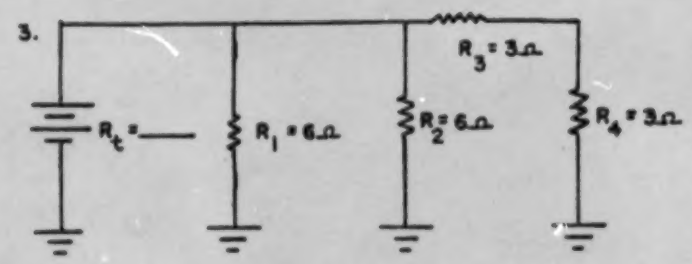


Note: Solve for the series circuit first.

2.

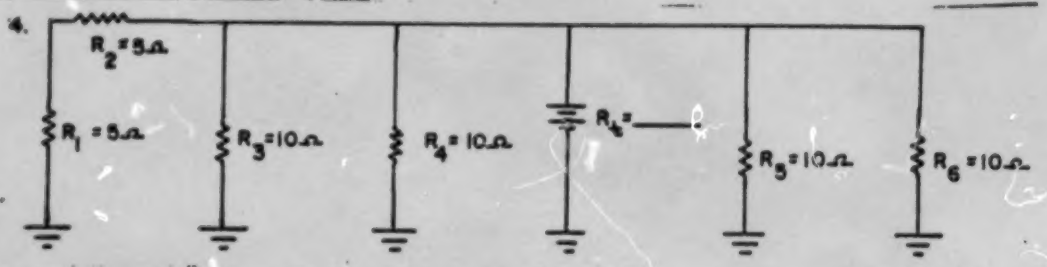


3.



Note: Solve for the series circuit first.

4.



Note: Solve for the series circuit first.

Answers to Frame 12: 1. 1.33Ω 2. 1.0Ω 3. 2.0Ω 4. 2.0Ω

Frame 13

When determining the TOTAL values in a parallel circuit, you must decide whether the characteristic to use is the SUM, SAME, or SMALLER THAN THE SMALLEST.

In the space provided on the response sheet, write the characteristic beside the work it describes.

a. Voltage: _____

b. Amperage: _____

c. Resistance: _____

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Answers to Frame 13:

a. Voltage: is the same through the parallel circuit

b. Amperage: is the sum of all the amperages in the parallel circuit

c. Resistance: is smaller than the smallest resistor in the parallel circuit

Frame 14

SAME _____ (E) _____ VOLTAGE

SUM _____ (I) _____ CURRENT (INTENSITY)

SMALLER THAN THE SMALLEST _____ (R) _____ RESISTANCE

If you remember them in this order, it's much easier.

If you really understand these characteristics, there are several problems in frame 15 that will help you see how true those characteristics are. It will show you how far you have come in the field of electricity and electronics too!

You should be able to solve all the problems in frame 15 using Ohm's Law.

$E = I \times R$, $I = \frac{E}{R}$, $R = \frac{E}{I}$ and the characteristics of parallel and series circuits.

Characteristics of SERIES CIRCUITS:

SUM: total voltage is the sum in a series circuit.

SAME: total amperage is the same in a series circuit.

SUM: total resistance is the sum in a series circuit.

Characteristics of PARALLEL CIRCUITS:

SAME: total voltage is the same as any voltage in the circuit.

SUM: total amperage is the sum of all the amperages in the circuit.

SMALLER THAN THE SMALLEST: total resistance is less than the smallest resistor.

NO RESPONSE REQUIRED

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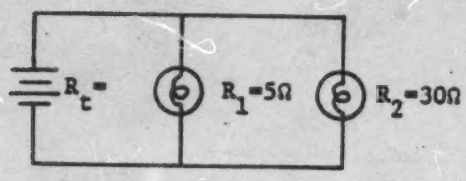
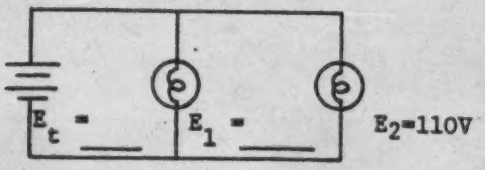
Solve the following and write the answers on the response sheet.

1.

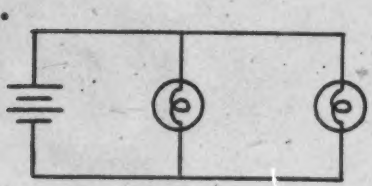
2.



3.

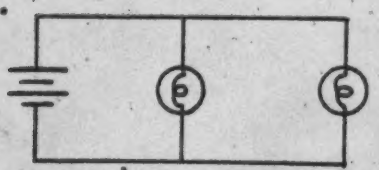


4.



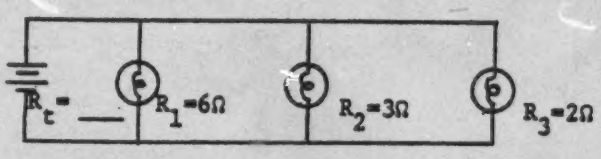
E_t=____	E_1=110V	E_2=____
I_t=2a	I_1=1a	I_2=1a
R_t=55Ω	R_1=____	R_2=110Ω

5.

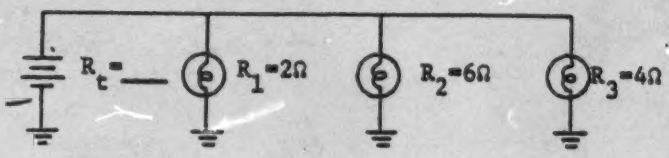


E_t=24V	E_1=____	E_2=____
I_t=____	I_1=2a	I_2=____
R_t=____	R_1=____	R_2=12Ω

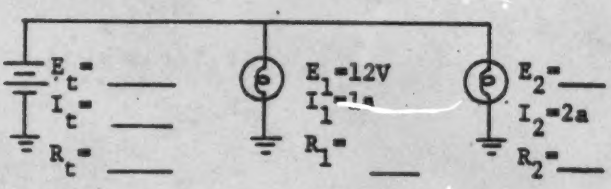
6.



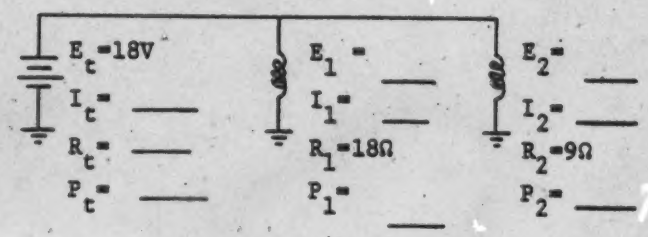
7.



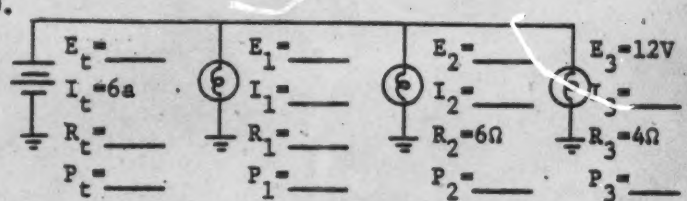
8.



9.



10.

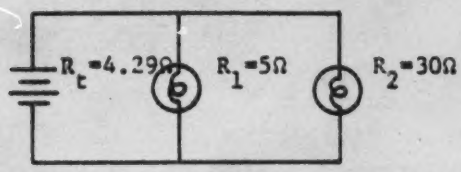


21

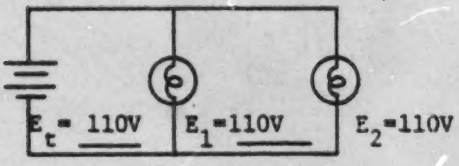
CORRECT RESPONSES FOR PARALLEL CIRCUITS in Frame 15:

1.

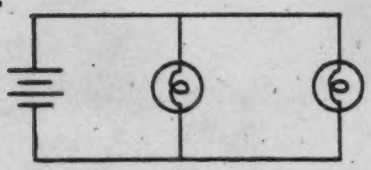
2.



3.

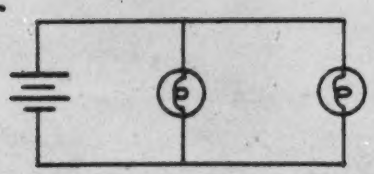


4.



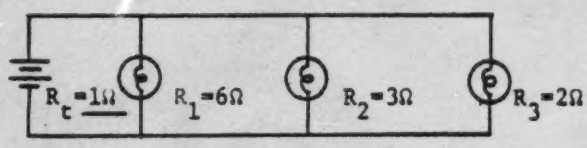
E_t=110V	E_1=110V	E_2=110V
I_t=2a	I_1=1a	I_2=1a
R_t=55Ω	R_1=110Ω	R_2=110Ω

5.



E_t=24V	E_1=24V	E_2=24V
I_t=4a	I_1=2a	I_2=2a
R_t=6Ω	R_1=12Ω	R_2=12Ω

6.



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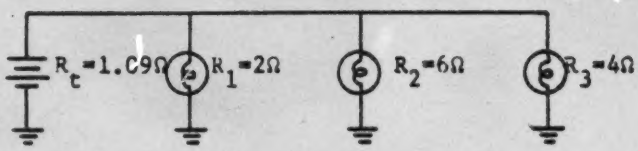

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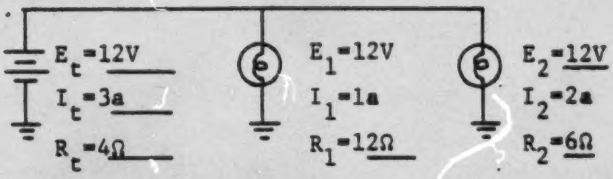
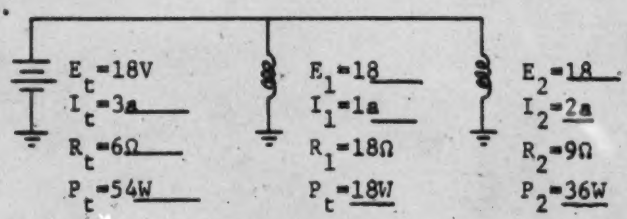


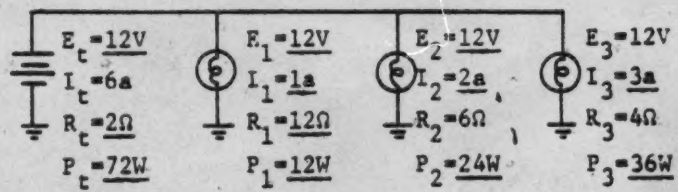
E_t=12V	E_1=12V	E_2=12V
I_t=3a	I_1=1a	I_2=2a
R_t=4Ω	R_1=12Ω	R_2=6Ω

9.



E_t=18V	E_1=18	E_2=18
I_t=3a	I_1=1a	I_2=2a
R_t=6Ω	R_1=18Ω	R_2=9Ω
P_t=54W	P_t=18W	P_2=36W

10.



E_t=12V	E_1=12V	E_2=12V	E_3=12V
I_t=6a	I_1=1a	I_2=2a	I_3=3a
R_t=2Ω	R_1=12Ω	R_2=6Ω	R_3=4Ω
P_t=72W	P_1=12W	P_2=24W	P_3=36W

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WORKBOOK

3ABR42331-WB- 118

Technical Training

Aircraft Environmental Systems Mechanic

PARALLEL CIRCUITS PERFORMANCE

17 August 1977

3350 TECHNICAL TRAINING WING
3370 Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE

DO NOT USE ON THE JOB

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Environmental Pneudraulics Branch
Chanute AFB, Illinois

3ABR42331-WB-111A

PARALLEL CIRCUITS PERFORMANCE

OBJECTIVES

Using a DC Fundamentals trainer, construct a parallel circuit and measure electrical values with one instructor assist allowed for each task area.

EQUIPMENT

	Basis of Issue
Trainer P/N 521685 DC Fundamentals	1/student
Multimeter	1/student

SAFETY

Caution: Remove watches, rings, bracelets, etc., before starting any work on equipment. It is also good safety practice to work on the equipment with one hand. This practice reduces the chances of receiving an electrical shock to some vital body organ when working with electricity. Also remember that light bulbs, resistors, etc., do get hot and could burn the skin.

PROCEDURE

Pay close attention to all direjtions that you are given in the workbook. When performing in the workbook, such as answering questions or recording electrical measurements, if your response is incorrect, restudy the information with instructor assistance as needed. Do not hesitate to ask the instructor questions. You will be required to accomplish several exercises and have some of them checked by your instructor before you move to the next exercise. You will also find that many of the exercises have the correct answers on page 7 . After you have completed all the exercises you will satisfactorily complete the progress check assigned by your instructor. Pages 12 through 16 may be removed for your convenience.

When you leave your trainer for scheduled or unscheduled breaks, complete the following checklist before you go.

1. Insure the SPST switch is turned off in the circuit.

2. Insure the 28V DC bus bar has all the electrical leads removed from it.

Supersedes 3ABR42231-WS-114A, 29 June 1971.
OPR: 3370TTG
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3370TTGTC - 600; TTVSR - 1

3. Insure the negative (black) bus bar has all the electrical leads removed from it.

4. Insure the multimeter is properly stored during this period.

a. Insure the controls are properly set for storage.

b. Leave the test leads attached to the meter.

c. Wrap the meter leads around the instrument.

d. Place the meter on the locker shelf.

5. When you return from break, take the same meter and go back to work.

Exercise 1. TRAINER PREPARATION

1. The metal plate on the right side of the trainer may be raised for your workbook to lay on.

2. Sign out a multimeter. See the lab instructor if assistance is needed.

3. Insure that the instructor has connected power to the trainer. You will do this by measuring the power with the multimeter at the positive (red) and negative (black) bus bars. These bus bars are located in the lower right and left hand corners of the trainer. If you don't read a voltage of 24 ± 4V DC, see your instructor.

4. Insure that fuse wire is across the fuse holders of each of the three (3) ammeters on the trainer. This will protect the ammeter's internal circuit from an overload. If the fuse wire is burned in two or is missing, see your instructor for assistance.

5. Pull the circuit breaker out (open) and turn OFF (open) two (2) single pole single throw (SPST) switches.

6. Insure all leads in the drawer are in good condition with a plug at both ends. If you find any damaged leads, give them to the instructor.

7. Examine the electrical lead ends, and note how you may connect them together if one lead is too short. See your instructor for assistance if needed.

Exercise 2

Note: In this exercise you are required to build a parallel circuit with two (2) loads which will be light bulbs, both sharing <u>one</u> common ground wire. Follow the steps given following.

1. Using the electrical leads from the drawer, construct the circuit shown in figures 1 through 3, consisting of a circuit breaker, SPST switch, and two light bulbs.

Note: If an electrical lead to too short you may connect leads together to prevent stretching or breaking them.

2. Before applying power to your circuit, be sure you have <u>one</u> path for current flow from the negative bus bar to the lights. Tracing from negative to positive, electrons first go to the common side of both lamps and from there they can go two different paths. One is through the first lamp and the other is through the second lamp. The electrons (current) will rejoin again at the common positive side of the light that is closest to the SPST switch, and follow one path to the positive bus bar. (You have formed a parallel circuit at the lights.)

STOP and have your instructor check your work at this time.

3. After the instructor has checked the circuit and with the instructor present, do the following:

a. Push the circuit breaker.

b. Turn the single pole single throw (SPST) switch ON. The lamps should now light. If the lamps do not light, turn OFF the SPST switch and ask the instructor for assistance.

c. If the lamps light and everything appears OK, turn the SPST switch OFF.

STOP and have your instructor initial here before you proceed.

Exercise 3

1. Measuring and proving current flow is the <u>sum</u> in a parallel circuit.

a. You will use all three (3) ammeters on the trainer to prove current is the <u>sum</u> of all the currents in a parallel circuit. Refer to figure 3 for the circuit construction. As you can see, this is the same circuit you have previously done. Refer to figure 4 for the ammeter hookup.

b. Using figure 4 in the exercise, you should have done the following in hooking up the ammeter.

(1) Connect an ammeter between checkpoints 2 and 4 remembering the polarity of the + and - of the ammeter to the circuit. The positive lead of the ammeter will go to the most positive point and the negative ammeter lead will go to the most negative point.

(2) Connect an ammeter between points 3-5.

(3) Connect an ammeter between points 7-8.

(4) Insure the polarities on all three meters are correct.

(5) Turn on the power and record the ammeter readings in figure 4. If you do not get a reading on the ammeter and/or the circuit breaker pops, or the fuse wire burns in two, turn OFF the power. Do not touch the circuit wiring and see your instructor. Do not leave or turn the switch back on if you didn't get a reading the first time. This could prevent internal damage to the meter.

(6) Check your readings you have recorded from figure 4 and if they were correct, move on to the set of questions. If your readings were wrong, check with your instructor before going on.

Answer the following questions using the information given so far in this workbook.

1. A parallel circuit provides at least _____ paths of current flow in the circuit.

2. Total current flow in a parallel circuit is the _____.

3. An ammeter is hooked in _____ with the rest of the circuit.

See page 7 for answers.

If your answers to the last set of questions are correct, proceed on. Turn off the power to the circuit and put all the leads in the drawer if you fully understand the exercise. If any questions arise, be sure to ask the instructor for assistance.

Note: In the previous exercise you proved that total current in a parallel circuit is the sum of all the currents in the circuit. Also that current in a parallel circuit must have two or more paths to follow.

Exercise 4

1. Measuring and proving that an increase in the number of paths of current flow will increase the total current in the whole circuit.

a. Using figure 5 and three lights in parallel, construct and measure the current in a three load circuit.

b. Hook up the circuit in figure 5. Notice that the circuit is just about the same as figure 4, but you have connected in one more light and are now using only two ammeters.

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(1) By hooking the ammeter between the circuit breaker and the switch, you are measuring the total circuit current. Also the second ammeter indicates the amperage in one light bulb which would be approximately the same for all the light bulbs.

(2) If you compare the two light bulb circuit in the previous exercise to the total reading in this exercise, you can see that by adding one more path of current flow (3rd light) the total current will increase.

(3) Record the amperage readings on figure 5, and check your answers. Then proceed on to answer the following questions.

Note: If you have any questions up to this point, please ask your instructor.

Answer the following questions using the information given so far in this workbook.

1. The current in a parallel circuit is the same/sum _____.

2. Adding more paths in a circuit will increase/decrease the total circuit current. _____

3. An ammeter is hooked in parallel/series with the circuit being measured. _____

See page 7 for answers.

If you have any questions, please ask your instructor at this time.

Take apart the circuit and proceed to the next exercise.

Exercise 5

1. Measuring and proving voltage is the same in a parallel circuit.

a. Using figure 6 as a guide, construct the circuit indicated on the trainer and take the voltmeter readings at the points indicated.

b. Record your findings of the exercise and check your answers on page 7 . If you are having trouble connecting the circuit ask your instructor for assistance. After you have connected the voltmeter, take the readings at the indicated checkpoints and record your answers on figure 6. If you receive the correct readings, take the circuit apart, and proceed to the progress check, page 8 .

ANSWER SHEET

Exercise 3

1. two or more
2. sum
3. series

Figure 4

2 - 4	1.3 ± .5 amps
3 - 5	1.3 ± .5 amps
7 - 8	2.5 ± .8 amps

Exercise 4

1. sum
2. increase
3. series

Figure 5

4 - 6	1.3 ± .5 amps
9 - 10	4.2 ± .3 amps

Exercise 5

Figure 6

1 - 2	24 ± 4V DC
3 - 4	24 ± 4V DC

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PROGRESS CHECK INSTRUCTIONS

This progress check will require you to correctly construct a parallel circuit and measure electrical values with one instructor assist allowed for each task area. Instructor assist for each task area is defined as an aid, such as technical direction or explanation, given a student who can proceed no further on his/her own. The instructor will initial your work after you have satisfactorily completed each task of the progress check. If you do not pass the progress check you will follow the instructions given by the instructor.

You will not communicate (talk, etc.) with other students during the progress check without your lab instructor's permission.

You will not use fellow students' work to solve the problems in this progress check.

You must satisfactorily complete this progress check before further progression to other lab progress checks.

Have your instructor select and initial on pages 9 or 10 the parallel circuit progress check you are to draw on figure 7. Using a lead pencil only, draw in the parallel circuit leads between the various symbols. Later you will construct this circuit on the trainer. After you have satisfactorily completed the progress check, you will follow the instructions on page 11.

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_____ Instructor's Initials. Assigned progress check #1.

Complete each task listed below. Do not go on until the instructor has initialed your work for that task.

Task 1 Draw the circuit for a 10 ohm resistor in parallel with a light, with a circuit breaker and a SPST switch on figure 7.

_____ Instructor's Initials Task Initials _____ _____

Task 2 Construct the parallel circuit drawn on figure 7 on the trainer and complete an operational check for the instructor.

_____ Instructor's Initials Task Initials _____ _____

Task 3 Measure and record the electrical values required below.

The total current flow _____. (amps)

The voltage across the resistor _____. (volts)

The voltage across the light _____. (volts)

Task Initials _____ _____

_____ Instructor's Initials

Turn to page 11 for further instructions.

Note: If the instructor provides an instructor assist for a task, the instructor will initial behind the task initials (see objectives).

691 Instructor's Initials. Assigned progress check #2.

After completion of each task listed below, do not progress until the instructor has initialed your work for that task.

Task 1 Draw the parallel circuit for two 10 ohm and one 500 ohm resistors. The circuit must also contain a SPST switch and a circuit breaker. Make your drawing on figure 7.

_____ Instructor's Initials. Task Initials _____ _____

Task 2 Construct the parallel circuit drawn on figure 7 on the trainer and complete an operational check for the instructor.

_____ Instructor's Initials. Task Initials _____ _____.

Task 3 Measure and record the electrical values required below.

The total current flow _____ amps.

The voltage across left resistor _____ volts.

The voltage across right resistor _____ volts.

The voltage across 500 ohm resistor _____ volts.

The total voltage _____ volts.

Task Initials _____ _____.

_____ Instructor's Initials

Turn to page 11 for further instructions.

Note: If the instructor provides an instructor assist for a task, the instructor will initial behind the task initials (see objectives).

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After you have satisfactorily completed the progress check you will do the following:

1. Put all the good leads in the drawer of the trainer.

2. Give the broken leads to the lab instructor with the parts.

3. Place the work table in the down position on the trainer.

4. Return the multimeter to its storage cabinet. Be sure the controls on the meter are set correctly for storage.

5. You will turn in your work to the lab instructor before you leave the lab area.

Note: You may review any part or all of this workbook if you wish, but your work will not leave the lab area without the lab instructor's permission.

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Exercise 2, Figures 1 through 3.

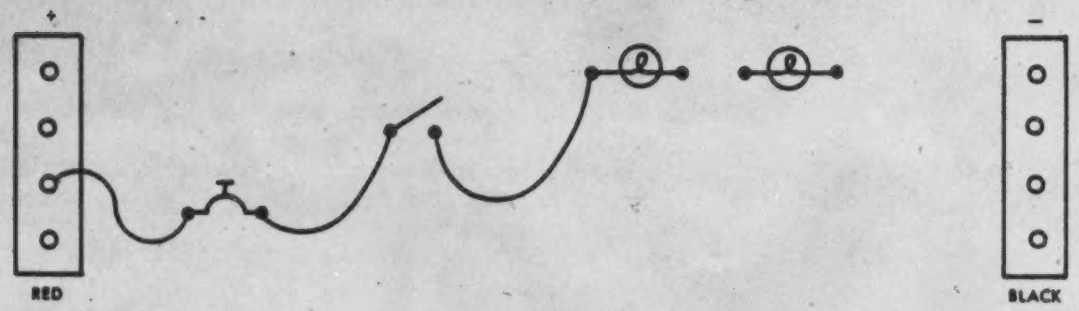

Figure 1.

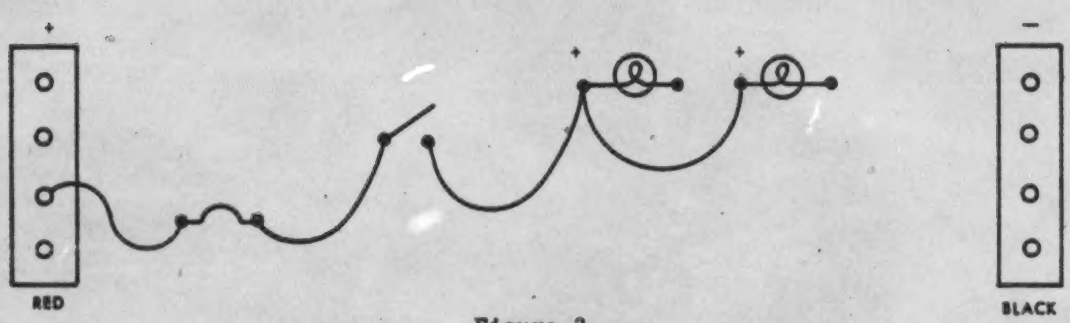

Figure 2.

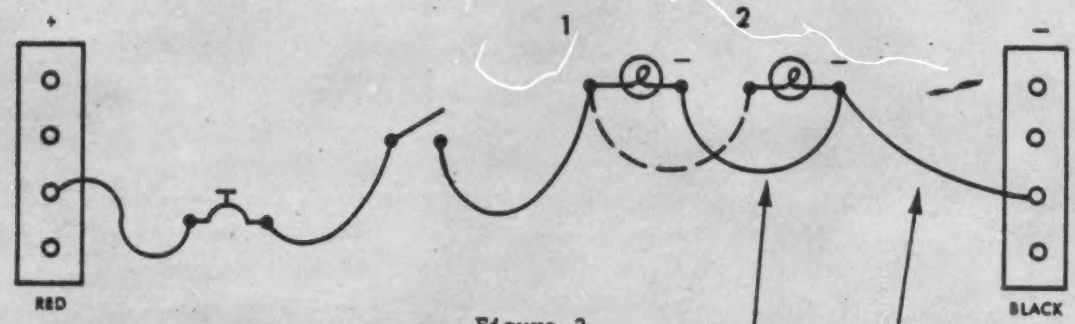

Figure 3.

Note: First light ground (negative side of load).

Second light ground (negative side of the load) and common ground for BOTH lights.

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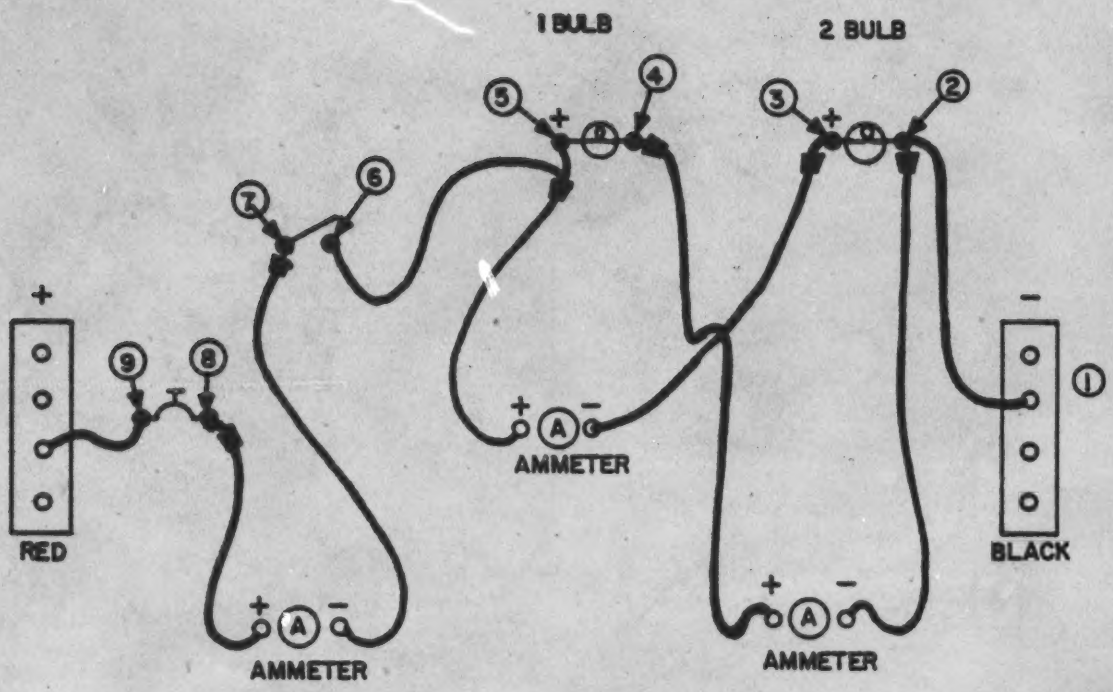

Figure 4.

CHECKPOINTS	AMPERAGE READINGS
2 - 4	_____ amps
3 - 5	_____ amps
7 - 8	_____ amps (TOTAL)

700

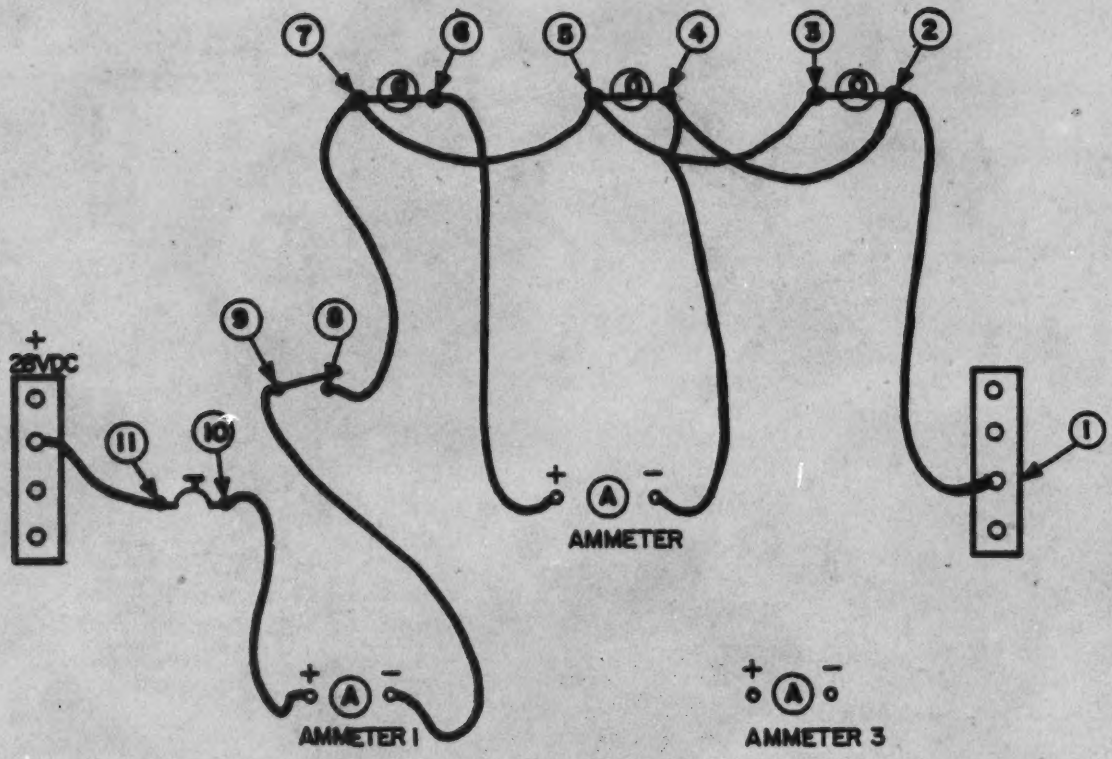

Figure 5.

CHECKPOINTS	AMPERAGE READINGS
4 - 6	_____ amps
9 - 10	_____ amps

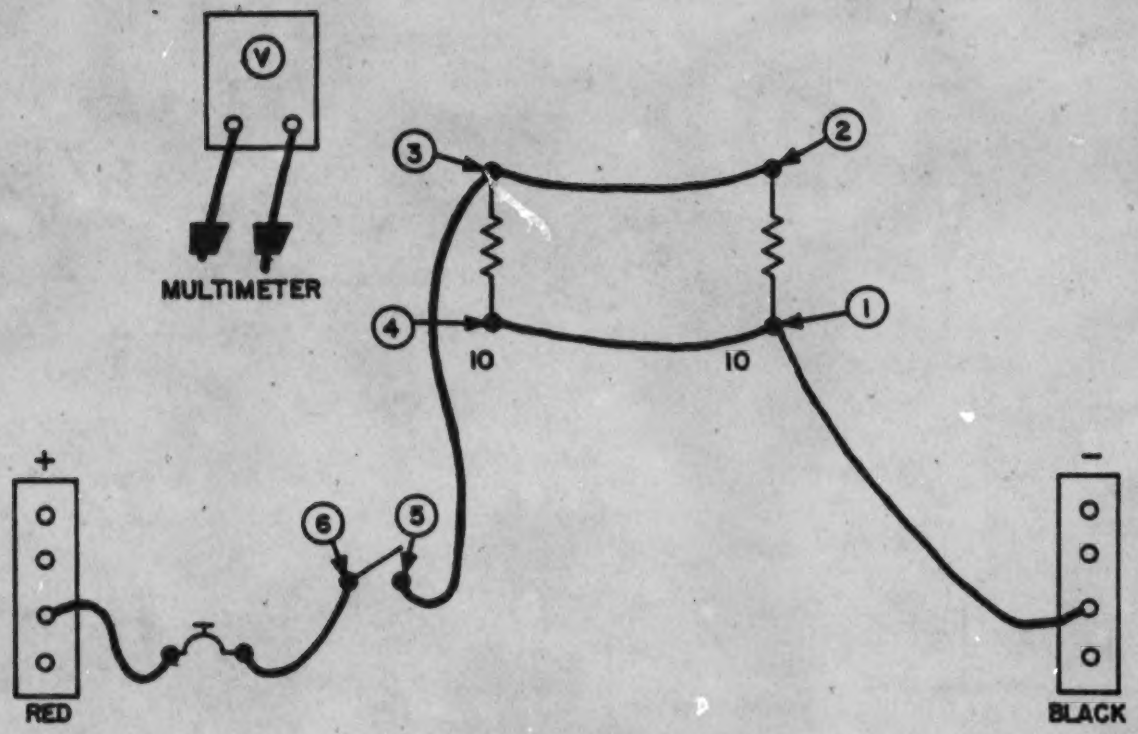

Figure 6.

CHECKPOINTS	VOLTAGE READINGS
1 - 2	_____ volts
3 - 4	_____ volts

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Figure 7.

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PROGRAMMED TEXT

3ABR42331-PT-119

Technical Training

Aircraft Environmental Systems Mechanic

SERIES-PARALLEL CIRCUITS

21 September 1977

3350 TECHNICAL TRAINING WING
3370 Technical Training Group
Chanute Air Force Base, Illinois

Designed for ATC Course Use.

Do Not Use on the Job.

699

FOREWORD

This programmed text was prepared for use in the 3ABR42331 Aircraft Environmental Systems Mechanic's Course. The materials contained herein were validated with students from the subject course. At least 90% of the students taking this text achieved or surpassed the criteria established in the lesson objectives. The average time for completion of this text was 6 hours and 15 minutes.

OBJECTIVES

1. Use Kirchhoff's current law to solve for unknown values in basic electrical circuits. A minimum of 8 out of 10 unknown values must be correct.

2. Use Kirchhoff's voltage law to solve for unknown values in basic electrical circuits. A minimum of 8 out of the 10 unknown values must be correct.

3. Use Ohm's law and power formulas to solve for unknown values in basic electrical circuits. A minimum of 8 out of the 10 unknown values must be correct.

4. Using schematic diagrams of electrical circuits, malfunction indications, and meter readings, select the type of trouble for a minimum of 8 out of 10 indications.

INSTRUCTIONS

This programmed text presents information in small steps called frames. Carefully study the written material and/or schematic in each frame until you are satisfied you understand its contents. Each frame requires you to respond to the information in some way. For example, you may be required to select true statements, solve problems, etc. Specific instructions are provided in each frame. After you have made your response on the response sheet compare your answer with the answers given on the top of the next frame. If you are correct, go on to the next frame. If you are incorrect, study the frame again and correct your mistakes before continuing. If you still can't understand your mistakes, ask your instructor for assistance. Read carefully, select the correct answer(s) and DO NOT HURRY. DO NOT MARK IN THIS TEXT.

SPECIAL INSTRUCTIONS

As you complete this PT you should have a copy of the laws and formulas (Handout 3ABR42331-HO-101B) in front of you for easy reference.

There are a number of frames in this PT in which the answers are not given. In these frames you are told to have the instructor check your answers. These frames have been included in the PT for a distinct purpose. Do not proceed any further in the PT until you have had your answers checked. For example, frame 13 requires you to have the instructor check your answers. Do not proceed to frame 14 until your answers to frame 13 have been checked.

OPR: 3370 TTG
DISTRIBUTION: X
3370 TTGTC - 400; TTVSR - 1

INTRODUCTION

You have just made a study of series and parallel circuits. Many circuits consist of both series and parallel units. A circuit of this type will be called a series-parallel circuit. No new formulas or laws are needed to solve for unknowns in series-parallel circuits. The only laws and formulas that you will need are in the handout that should be in front of you this time.

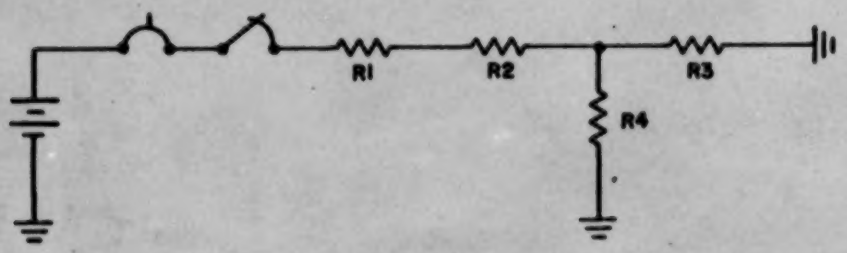
Frame 1

Do not start this frame unless you have a copy of the laws and formulas in front of you. See your instructor for them if necessary.

A series-parallel circuit is shown below. In this circuit R_2 and R_3 are connected in parallel with each other. R_1 is connected in series with the parallel combination of R_2 and R_3.

Mark the correct answer for each of the following questions on the response sheet. Use the circuit shown below.

1. The two resistors which are in parallel with each other are
   a. R_3 and R_4.
   b. R_1 and R_2.
   c. R_2 and R_3.
   d. R_1 and R_4.
2. The circuit shown is a
   a. series circuit.
   b. parallel circuit.
   c. series-parallel circuit.



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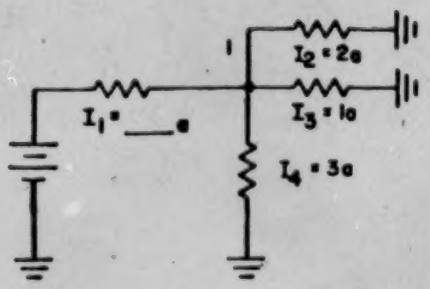
Answers to Frame 1: 1. a 2. c

Frame 2

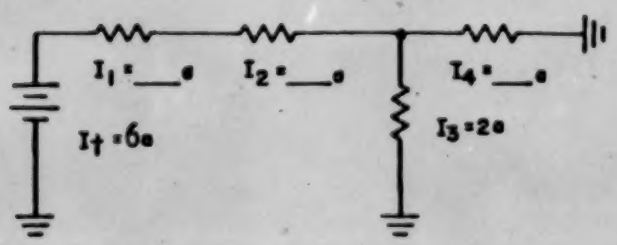
No new laws or formulas are needed to solve series-parallel circuits. In this PT we will review each of the laws and formulas with you. In the circuit shown below we want to find I_1. Applying Kirchhoff's current law to junction 1, the sum of the currents flowing into junction 1 is equal to 2 + 1 + 3 or 6a. Since 6a flows into junction 1, 6a must leave junction 1. Thus, $I_1 = 6a$.

DO NOT MARK ON THIS PAGE

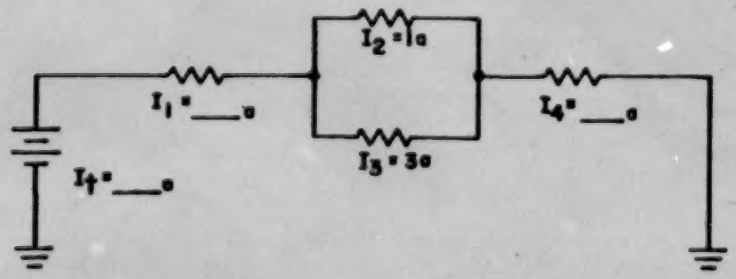


Using Kirchhoff's current law from your handout, solve for the unknown currents in each of the following circuits. Put your answers on the appropriate blanks on the response sheet.

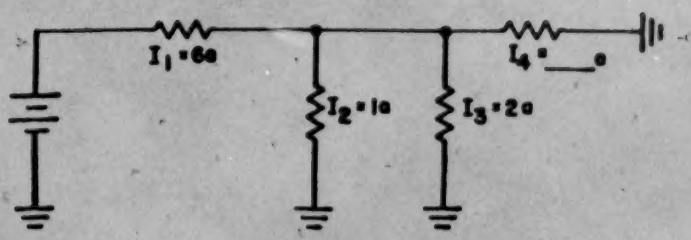
1.



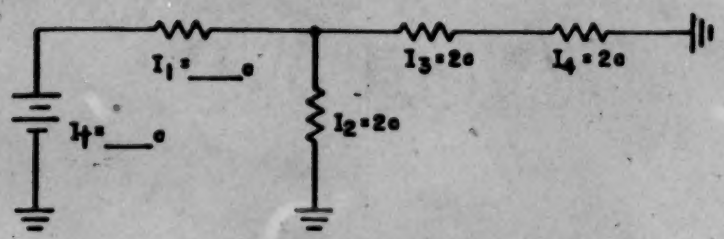
2.



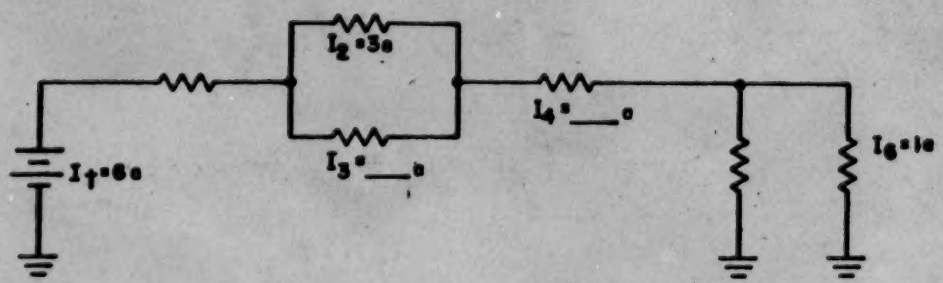
3.


I_1 = 6Ω
I_2 = 1Ω
I_3 = 2Ω
I_4 = ___ Ω

4.


I_1 = ___ Ω
I_2 = 2Ω
I_3 = 2Ω
I_4 = 2Ω
I_t = ___ Ω

5.


I_2 = 3Ω
I_3 = ___ Ω
I_4 = ___ Ω
I_t = 6Ω
I_6 = 1Ω

Answers to Frame 2: 1. I_1 = 6a, I_2 = 6a, I_4 = 4a, 5. I_3 = 3a, I_4 = 6a
2. I_1 = 4a, I_4 = 4a, I_t = 4a
3. I_4 = 3a
4. I_1 = 4a, I_t = 4a

Frame 3

Kirchhoff's voltage law is also used to solve for unknowns in a series-parallel circuit. In the circuit shown below we want to find E_t. To find E_t we need to know all the voltage drops around a closed path. Since we do not know the voltage dropped on R_3 and R_6, we will not use the path in which they are located. Instead we will use the R_5, R_4, R_2, and R_1 path. Apply Kirchhoff's voltage law to this path. We have 6 + 3 + 6 + 10 = 25V. Thus, E_t = 25V.

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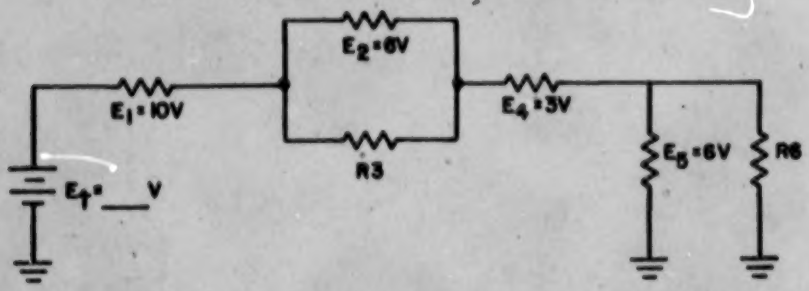
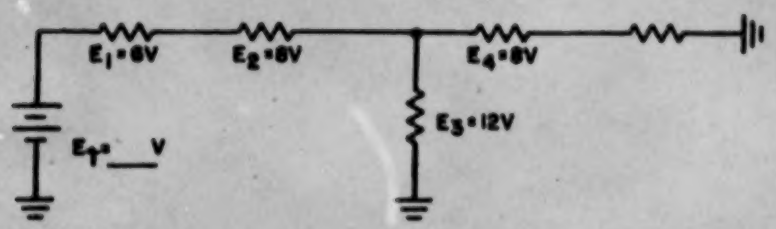


Using Kirchhoff's voltage law from your handout, solve for the unknown voltages in each of the following circuits. Put your answers on the appropriate blanks on the response sheet.

1.



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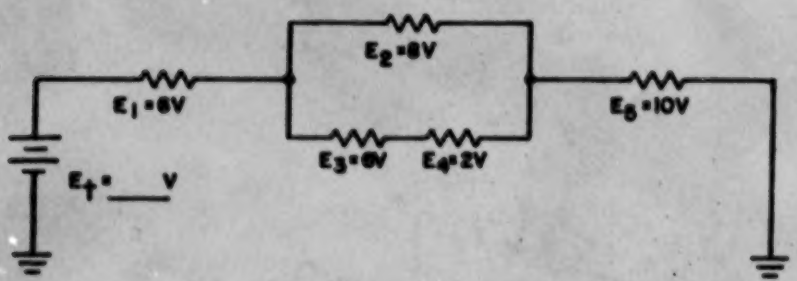

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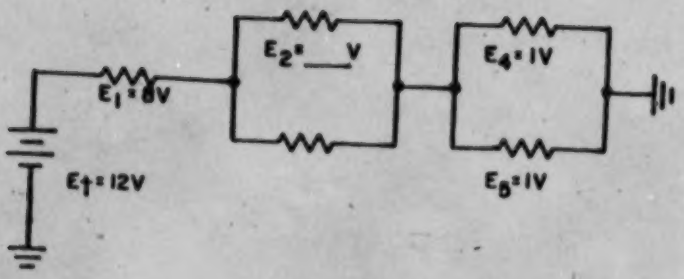
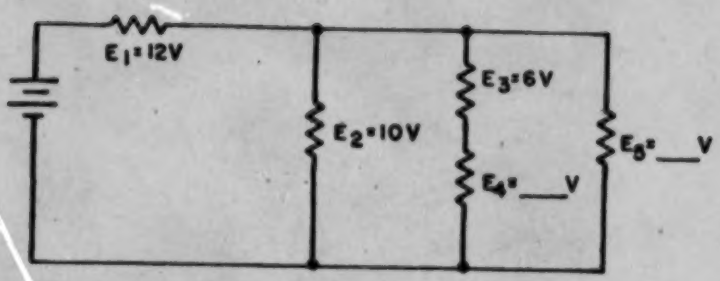
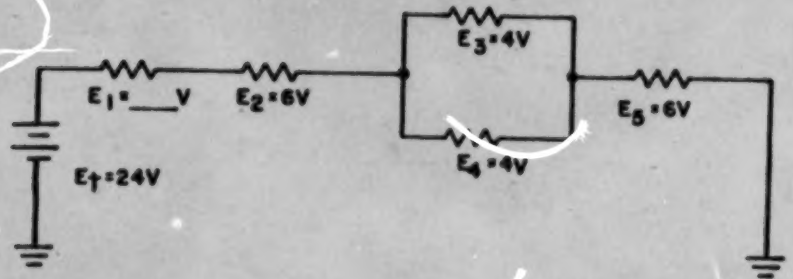

E1=8V
E2=___V
E4=1V
Et=12V
E3=1V

4.


E1=12V
E2=10V
E3=6V
E4=___V
E5=___V

5.


E1=___V
E2=6V
E3=4V
E4=4V
E5=6V
Et=24V

705

Answers to Frame 3: 1. E_t = 26V, 2. E_t = 24V, 3. E_2 = 3V, 4. E_4 = 4V, E_5 = 10V

5. E_1 = 8V

Frame 4

Ohm's law formulas are also used to find unknowns in series-parallel circuits. In the circuit shown below we want to find I_1. When using Ohm's law formulas be sure that the values used are for the same component. For example, to find I_1 we would use E_1 and R_1. Thus, $I_1 = E_1/R_1 = 12/4 = 3a$.

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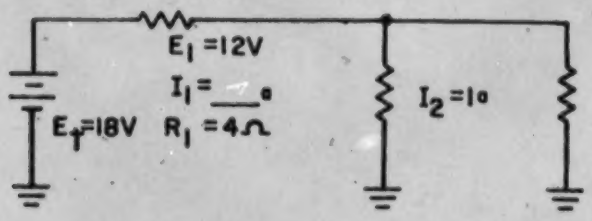
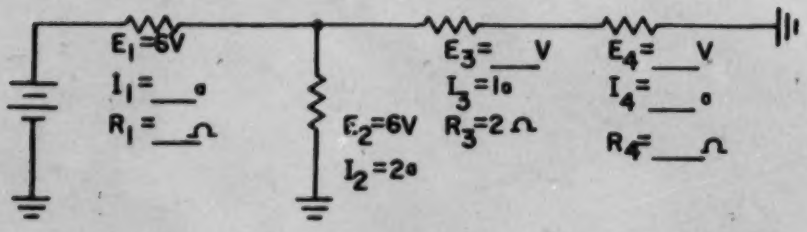
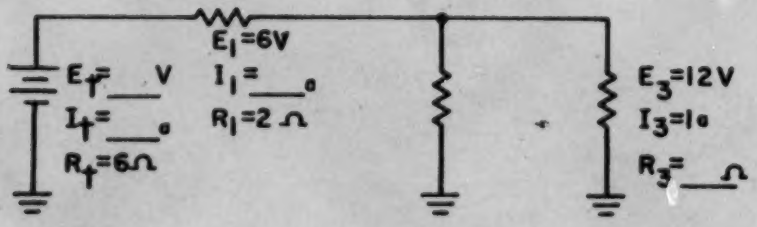


Using Kirchhoff's voltage and current law and Ohm's law formulas, solve for the indicated unknowns in each of the following problems. Write your answers on the response sheet.

1.



2.



Answers to Frame 4:

1. I_1 = 3a, E_3 = 2V, E_4 = 4V, 2. E_t = 18V, I_1 = 3a, R_3 = 12Ω

R_1 = 2Ω, I_4 = 1a I_t = 3a

R_4 = 4 Ω

Frame 5

Now let's look at how to find the total resistance in a series-parallel circuit. Since R_3 and R_4 are in parallel with each other in circuit A, we can use either the "product over the sum formula" or the "reciprocal formula" to find the series equivalent resistance of R_3 and R_4. Using the "product over the sum formula" we have

$$R_{34} = \frac{R_3 \times R_4}{R_3 + R_4} = \frac{12 \times 6}{12 + 6} = 72/18 = 4 \text{ ohms.}$$

Circuit B is the same as circuit A except we have replaced R_3 and R_4 by their series equivalent resistor R_{34}. Now we have a series circuit. In a series circuit the total resistance is equal to the sum of the individual resistances. Thus, $R_t = 16 + 6 + 4 = 26$ ohms.

Note: To find the total resistance of a series-parallel circuit, first find the series equivalent resistances of the parallel parts and then you just have a series circuit.

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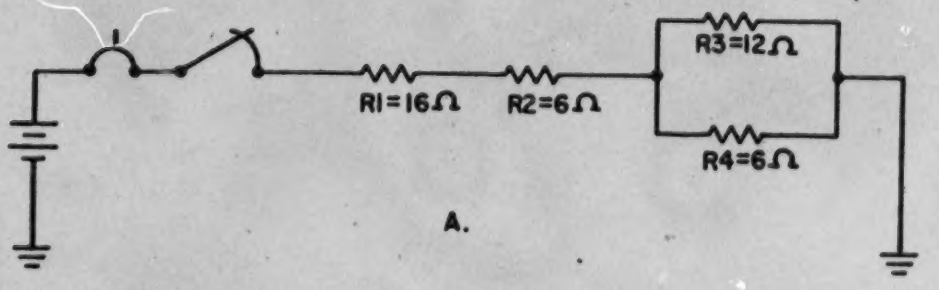
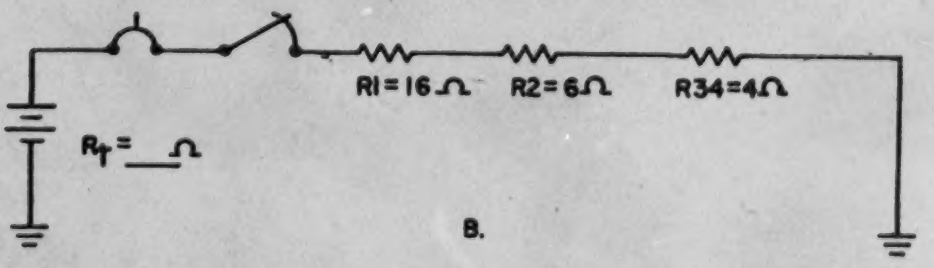


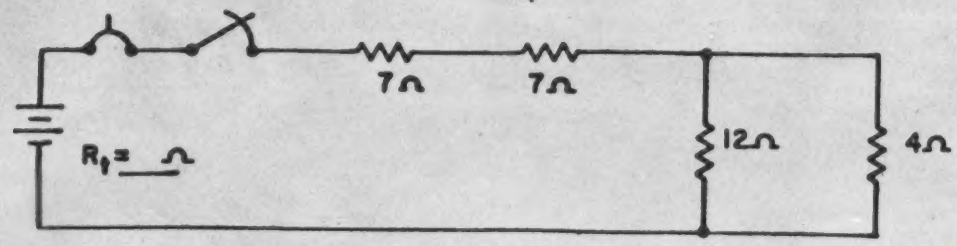
A.



B.

Find the total resistance in each of the following circuits and put your answers on the appropriate blank on the response sheet.

1.



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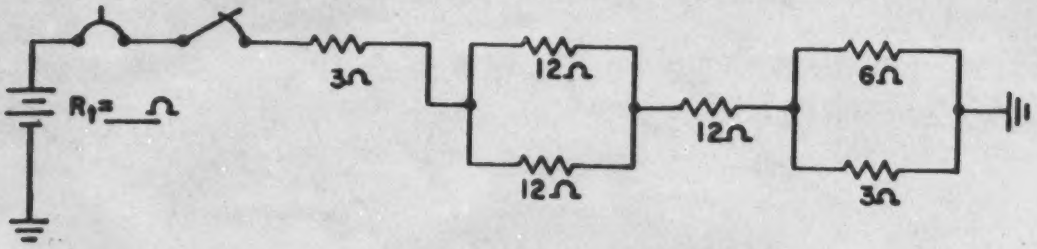

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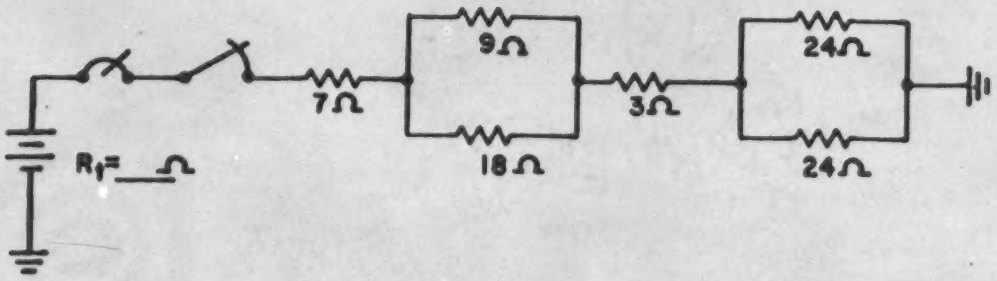
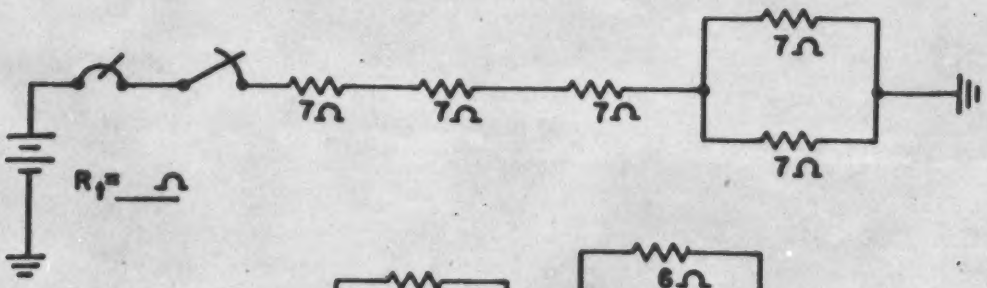
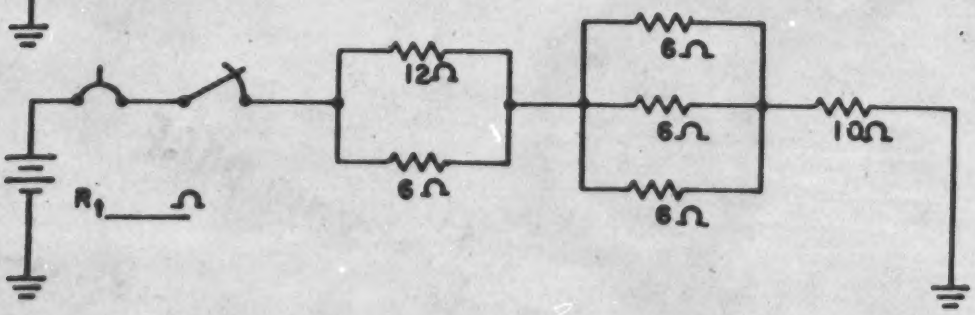


4.



5.



Answers to Frame 5:

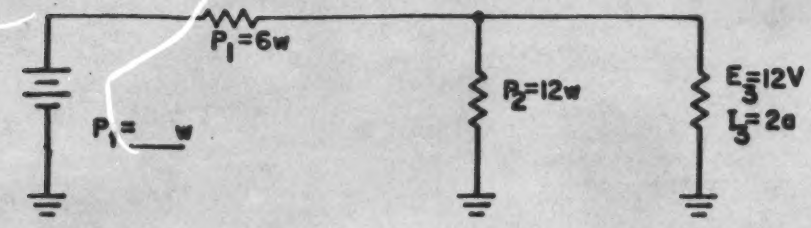
1. R_t = 17Ω, 2. R_t = 23Ω, 3. R_t = 28Ω, 4. R_t = 24.5Ω, 5. R_t = 16Ω

Frame 6

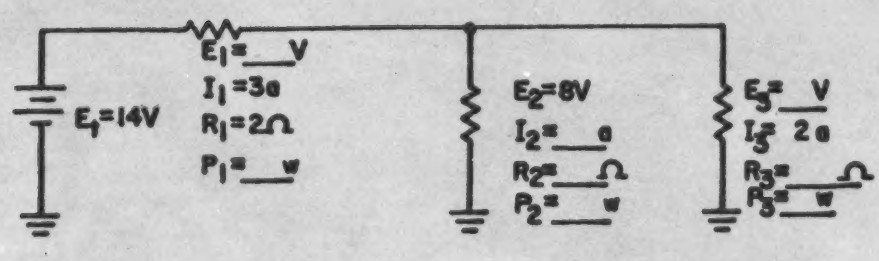
To find power you use the formula P = I X E. The total power in ANY circuit is equal to the sum of the powers used in the individual units. This can be expressed as a formula by $P_t = P_1 + P_2 + P_3$.

Solve for all indicated unknowns in the circuits shown below. Put your answers on the appropriate blanks on the response sheet.

1.



2.



709

Answers to Frame 6: 1. 42W, 2. E_1 = 6V, I_2 = 1a, E_3 = 8V
P_1 = 18W, R_2 = 8Ω, R_3 = 4Ω
P_2 = 8W P_3 = 16W

Frame 7

So far in this PT we have reviewed all the formulas and laws that are on your handout. We have seen how they are used to solve for unknowns in series-parallel circuits. Remember, if you can't apply one law to a particular circuit, try using a different one until you find one that can be used. In this and the next two frames we will solve the problem shown below step-by-step with you. Since we do not have any voltage readings we cannot use Kirchhoff's voltage law. However, we can use Kirchhoff's current law. Since there are 3a that leave the battery there must be a 3a that flow through R_4. Fill in 3a for I_4 on the response sheet. Applying Kirchhoff's current law to junction A we have 3a flowing into junction A. Thus, there must be 3a leaving junction A. Since 2a flows through R_3, 1a must flow through R_2. Fill in 1a for I_2. The sum of the currents flowing into junction B (I_2 + I_3) is equal to the current leaving junction B. Thus, 3a leaves junction B and I_1 = 3a. Fill in 3a for I_1.

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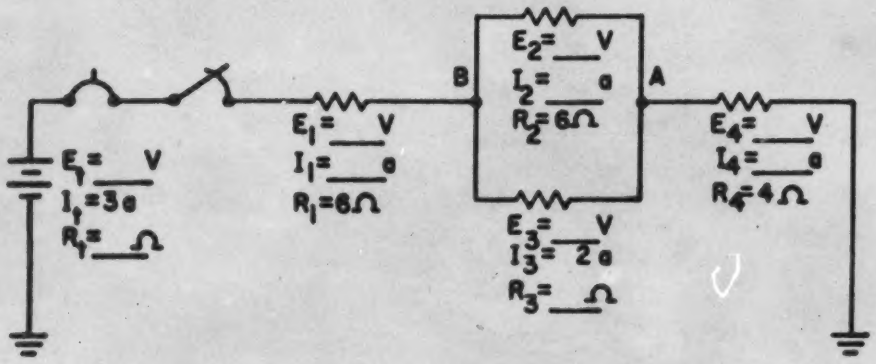
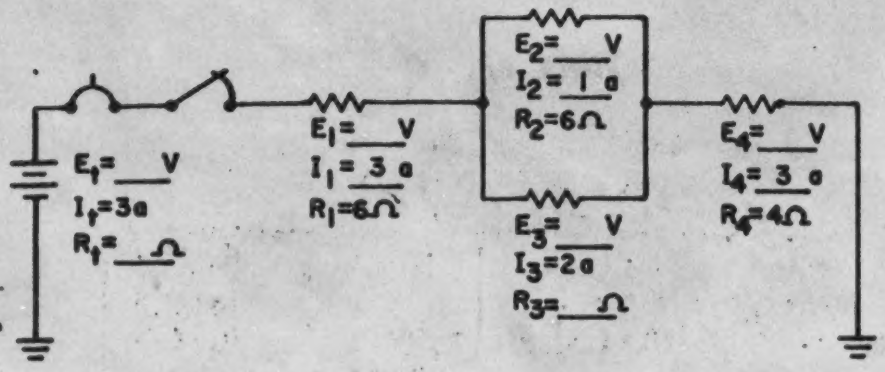


No further response required, proceed to the next frame.

715

This is the same circuit as in the last frame. The values for I_1, I_2, and I_4 that you found in frame 7 have been filled in for you. We still don't have enough information to use Kirchhoff's voltage law. However, we can use the Ohm's law formula E = I X R to find E_1, E_2, and E_4. $E_1 = I_1 \times R_1 = 3 \times 6 = 18V$. $E_2 = I_2 \times R_2 = 1 \times 6 = 6V$.

$E_4 = I_4 \times R_4 = 3 \times 4 = 12V$. Fill in these values on the correct blanks on the response sheet. We'll finish the problem in the next frame.

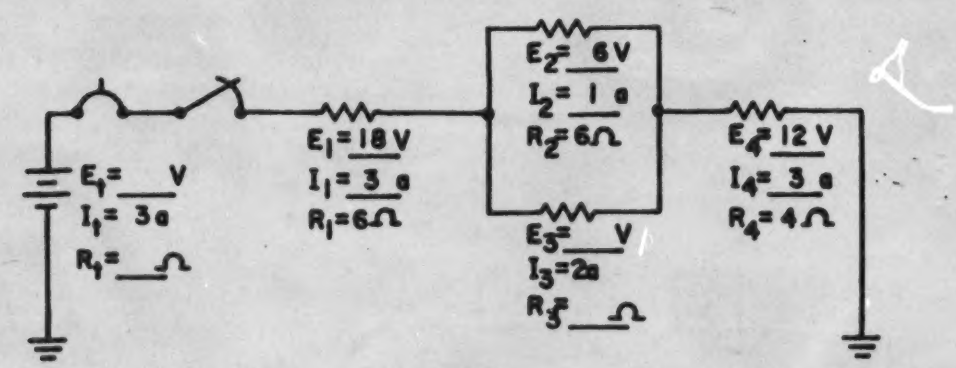


No further response required, proceed to the next frame.

711
Frame 9

We will finish the problem we started in frame 7. We have filled in the values that we have found so far. Now we can use Kirchhoff's voltage law. Applying Kirchhoff's voltage law to the path that contains R_4, R_2, and R_1, we have $E_t = E_4 + E_2 + E_1 = 12 + 6 + 18 = 36V$. Fill in 36V for E_t. We now can use Kirchhoff's voltage law to find E3 Apply Kirchhoff's voltage law to the path that contains R_4, R_3, and R_1. We have $E_t = E_4 + E_3 + E_1$. Substituting we have $36 = 12 + E_3 + 18$. Subtracting 30 from 36 we have $E_3 = 6V$. Fill in 6V for E_3 on the response sheet.

Now we can use Ohm's law formula $R = E/I$ to find R_t and R_3 $R_t = E_t/I_t = 36/3 = 12$ ohms. $R_3 = E_3/I_3 = 6/2 = 3$ ohms. Now the problem is solved.

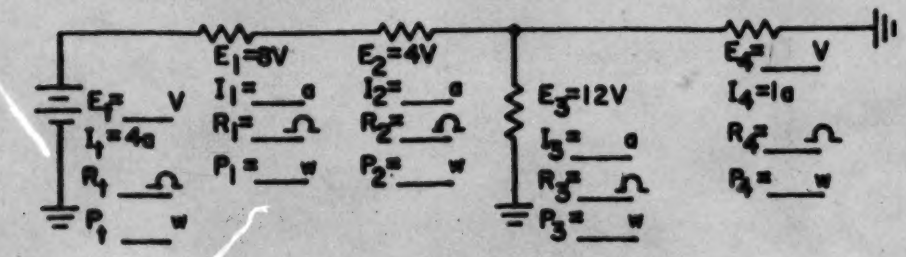


No further response required, proceed to the next frame.

717

Solve each of the following problems for the indicated unknowns. Put your answers on the appropriate blanks on the response sheet.

1.



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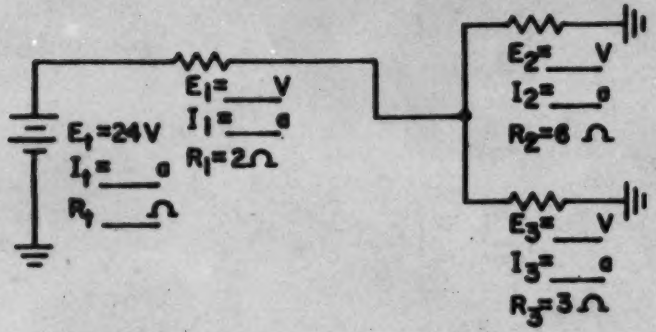

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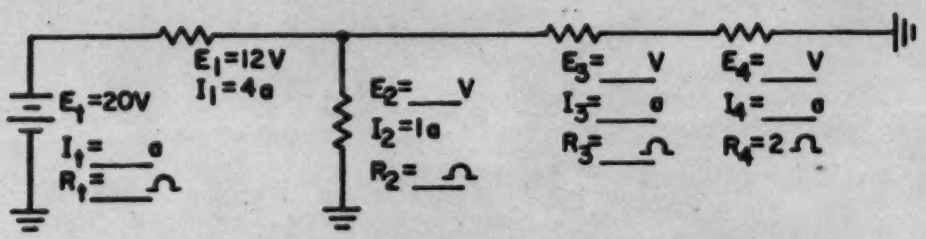


713

Answers to Frame 10: 1. E_t = 24V I_1 = 4a I_2 = 4a E_3 = 3a E_4 = 12V

R_t = 6Ω R_1 = 2Ω R_2 = 1Ω R_3 = 4Ω R_4 = 12Ω

P_t = 96W P_1 = 32W P_2 = 16W P_3 = 36W P_4 = 12W

2. I_t = 6a E_1 = 12V E_2 = 12V E_3 = 12V

R_t = 4Ω I_1 = 6a I_2 = 2a I_3 = 4a

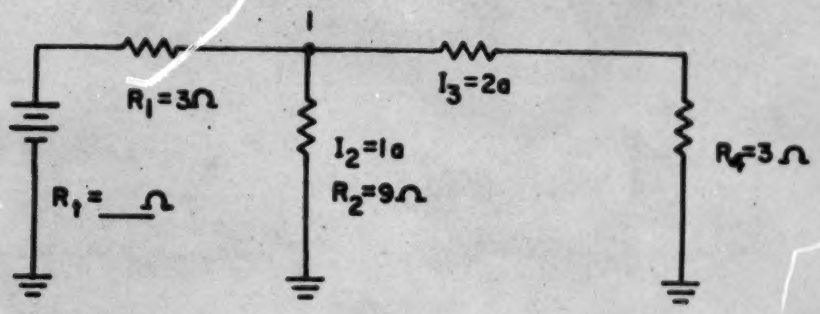
3. I_t = 4a E_2 = 8V E_3 = 2V E_4 = 6V

R_t = 5Ω R_2 = 8Ω I_3 = 3a I_4 = 3a

R_3 = .66Ω

Frame 11

In the circuit shown we want to find the value of R_t. To establish a procedure for solving series-parallel circuits we will work this problem step-by-step with you. As you complete each of the following steps place a check on the blank by the number of that step on the response sheet.



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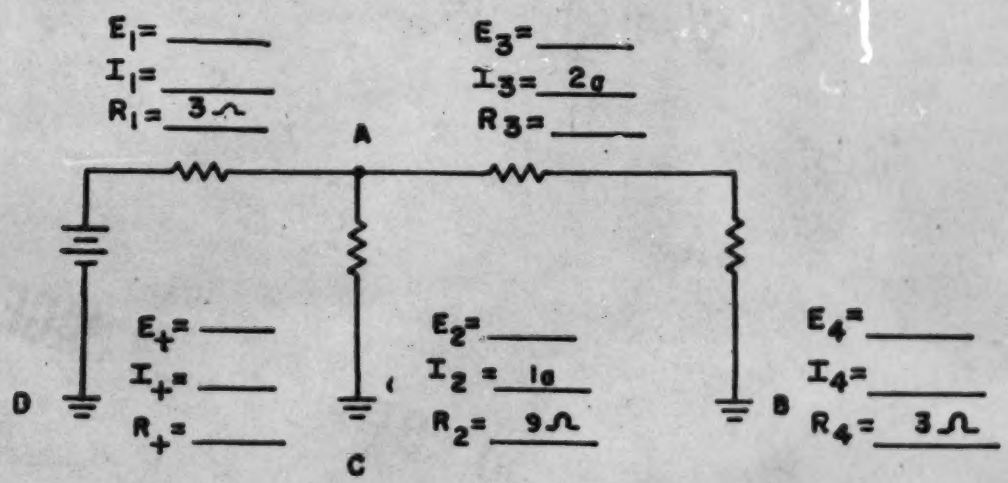
First draw the above circuit on scratch paper with all the E, I, R, known and unknowns, along with the letter for points A, B, C, and D as shown below.



_____ 1. Examining the circuit you can see the first step in this circuit should be to solve for E_2. Why? Because only Ohm's law is needed to solve for E_2. $R_2 \times I_2 = 9\Omega \times 1a = 9v = E_2$. Now you have the voltage at point A to point C. Because C and B are both ground points you will also have 9 volt from point A to point B. Remember A to C is in parallel with A to B, but A to B is a series circuit by itself.

_____ 2. Because Kirchhoff's current law states current flow in a series circuit is the same, I_4 must be equal to I_3 therefore, $I_4 = 2a$.

_____ 3. Now solve for E_4 by using Ohm's law. $I_4 \times R_4 = 2a \times 3\Omega = 6v = E_4$.

_____ 4. Now solve for E_3 by using Kirchhoff's voltage law. Subtract the voltage $E_4 = 6v$ from the total voltage (9v) across points A to B, which is 9v, $E_3 = 9v - 6v = 3v$. Now do you see how E_3 does equal 3v? If not, see Kirchhoff's voltage law and/or your instructor.

_____ 5. To solve for R_3 you must use Ohm's law.

$$R_3 = E_3/I_3 = 3v/2a = 1.5\Omega$$

_____ 6. Now you must find the total current. To do this you use Kirchhoff's current law. Add the current (2 amp) from circuit A and B to the current (1 amp) from A and C. This 3 amps will join at a point A, and will return to the positive point of the power sources. This means $I_1 = 3$ amp and also $I_t = 3$ amp.

_____ 7. Now that you know that $I_1 = 3a$ you can now apply Ohm's law and solve for E_1, $E_1 = I_1 \times R_1 = 3a \times 3\Omega = 9v$

_____ 8. Circuit A to B is in parallel with circuit A to C and the characteristic rules of a parallel circuit say that voltage is the same in a parallel circuit. To solve for E_t you must add the A to B voltage OR the A to C voltage to E_1 which will equal E_t, $E_t = 9v + 9v = 18v$.

_____ R_t Now to solve for R_t you must use Ohm's law.

$$R_t = \frac{E_t}{I_t} = \frac{18v}{3a} = 6\Omega$$

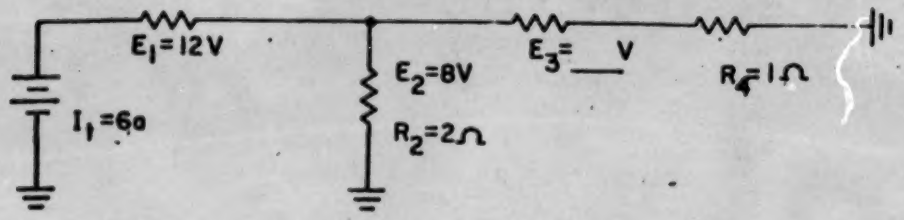
715

Answers to Frame 11: R_t = 6 ohms

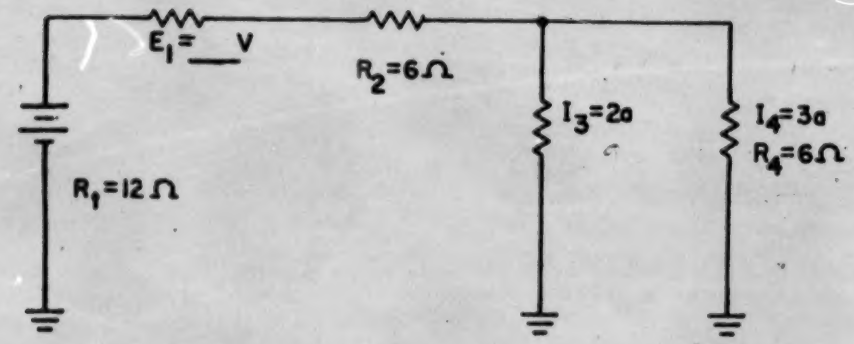
Frame 12

Solve each of the following problems for the indicated unknown. Put your answers on the appropriate blanks on the response sheet. Set up the problems, using the same procedure as in the last frame.

1.



2.



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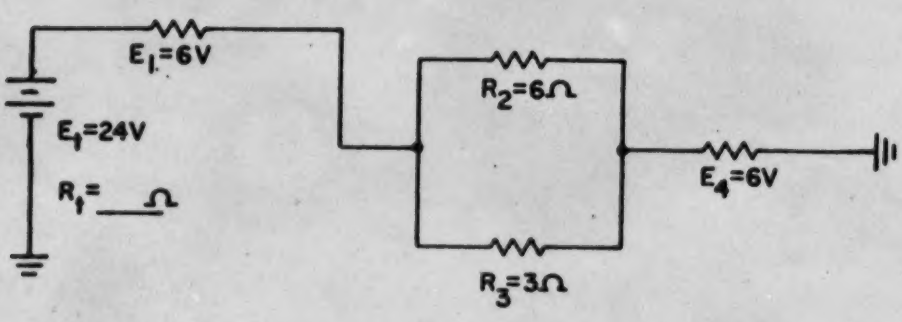

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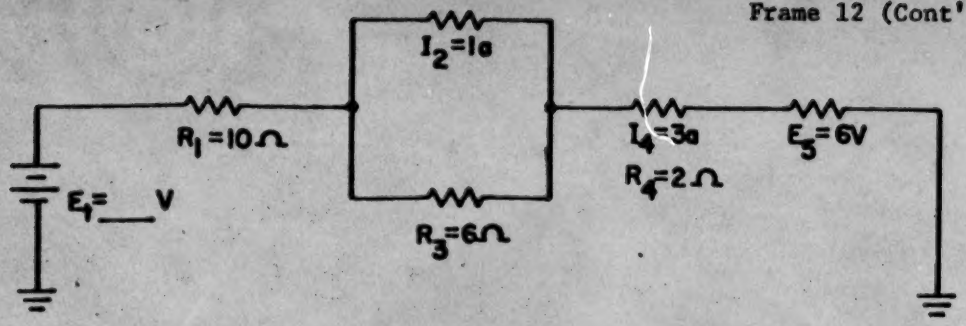
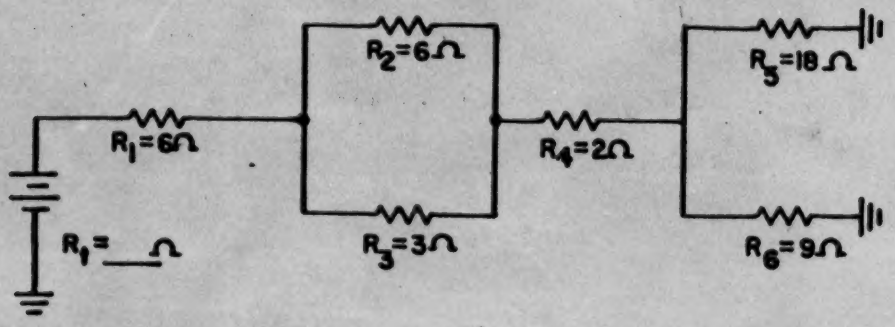
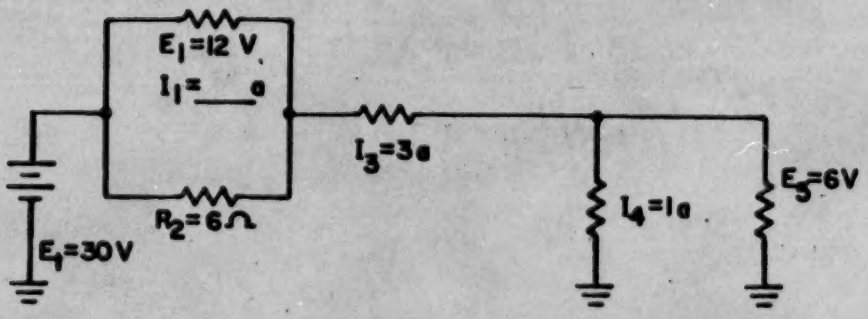

I_2=1a
R_1=10Ω
I_4=3a
E_5=6V
R_4=2Ω
E_1= ___ V
R_3=6Ω

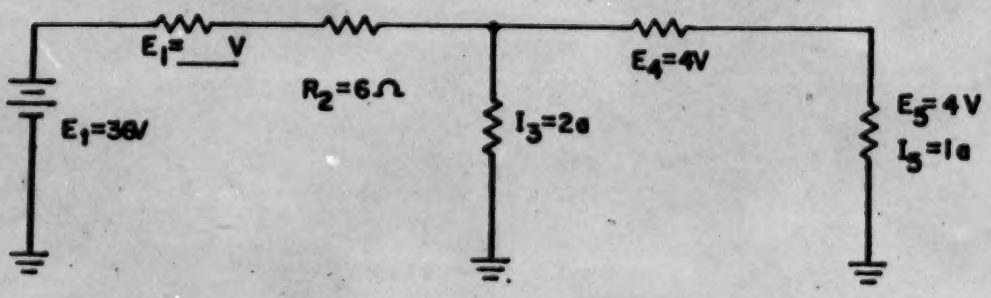
5.


R_2=6Ω
R_5=18Ω
R_1=6Ω
R_4=2Ω
R_1= ___ Ω
R_3=3Ω
R_6=9Ω

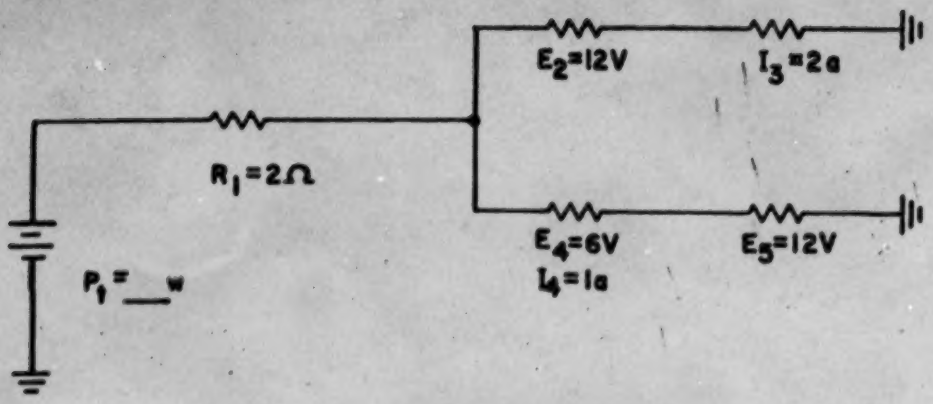
6.


E_1=12 V
I_1= ___ a
I_3=3a
E_5=6V
I_4=1a
R_2=6Ω
E_1=30V

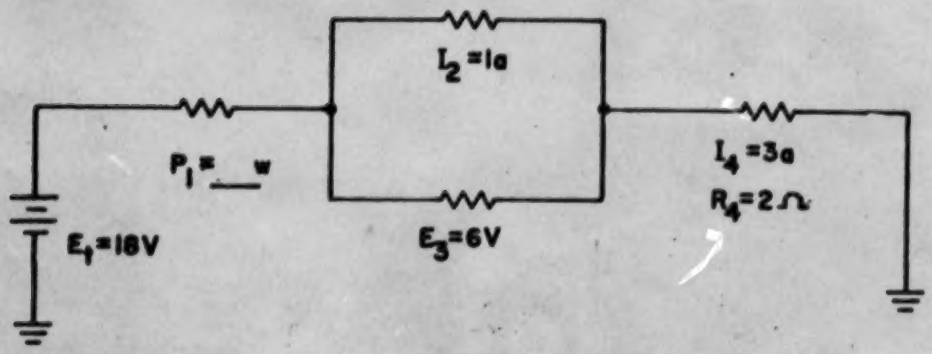
7.


E_1= ___ V
E_4=4V
R_2=6Ω
E_5=4 V
I_3=2a
I_5=1a
E_1=36V

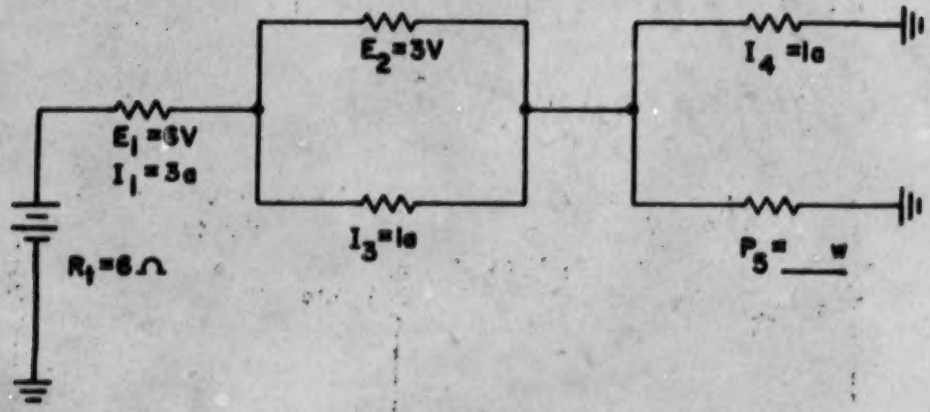
8.


E_2=12V
I_3=2a
R_1=2Ω
E_4=6V
I_4=1a
E_5=12V
P_1= ___ w

9.


I_2=1a
P_1= ___ w
I_4=3a
R_4=2Ω
E_1=18V
E_3=6V

10.

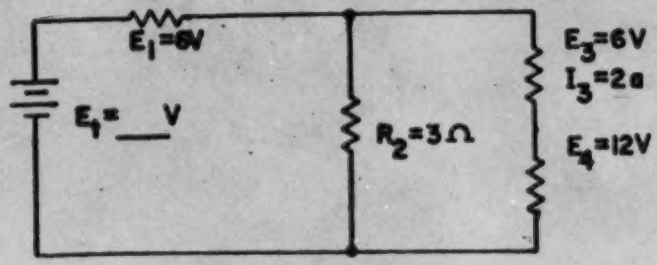

E_2=3V
I_4=1a
E_1=3V
I_1=3a
I_3=1a
R_1=6Ω
P_5= ___ w

Answers to Frame 12: 1. 6v, 2. 12v, 3. 4 ohms, 4. 54V 5. 16 ohms, 6. 1a 7. 10v 8. 72W, 9. 18W, 10. 18W

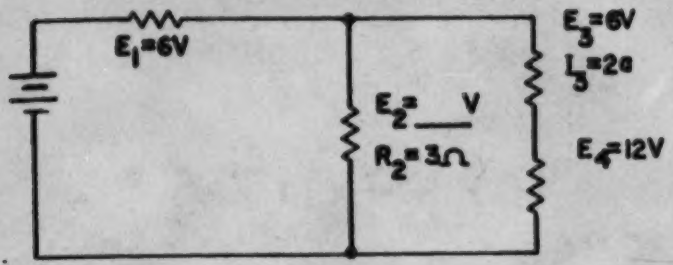
Frame 13

Solve each of the following problems for the indicated unknown. Put your answers on the appropriate blanks on the response sheet.

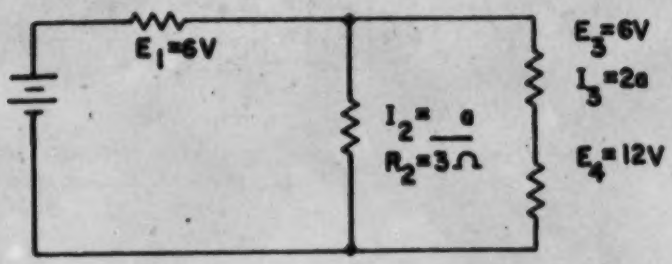
1.



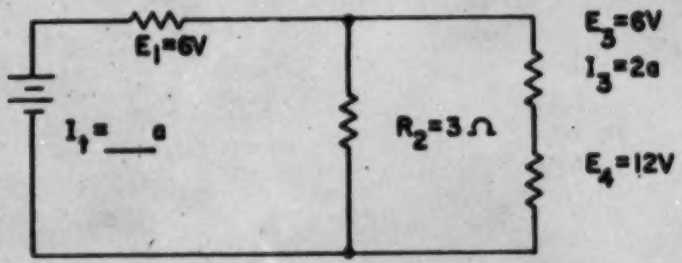
2.



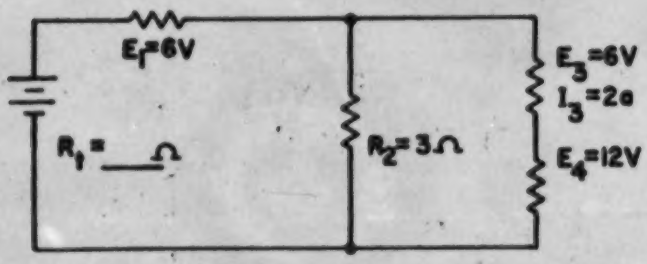
3.



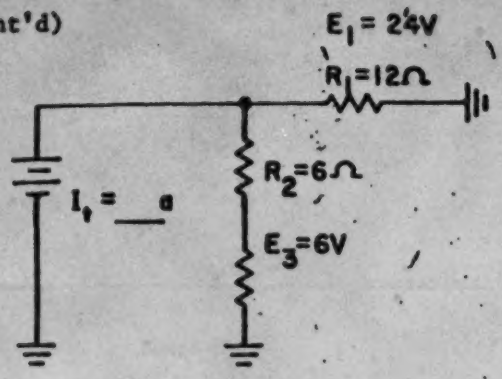
4.



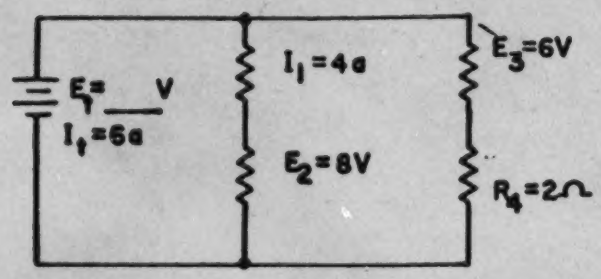
5.



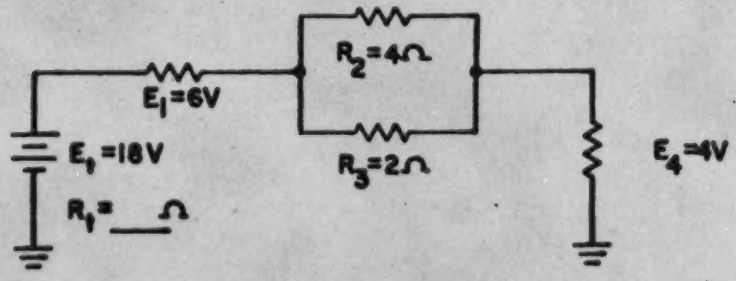
6.


E1 = 24V
R1=12Ω
R2=6Ω
I1 = ___ a
E3=6V

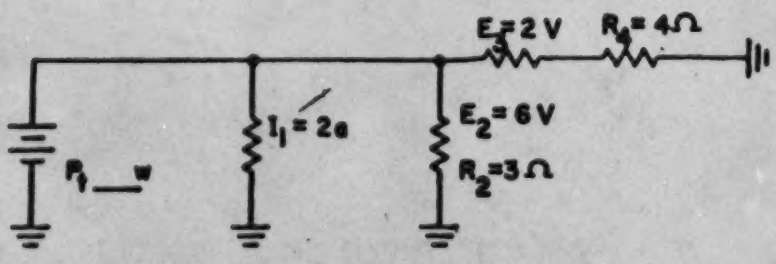
7.


E3=6V
I1=4a
E1= ___ V
I1=6a
E2=8V
R4=2Ω

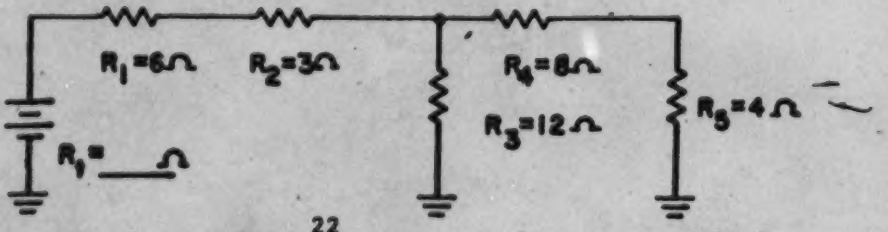
8.


R2=4Ω
E1=6V
E1=18V
R3=2Ω
E4=4V
R1= ___ Ω

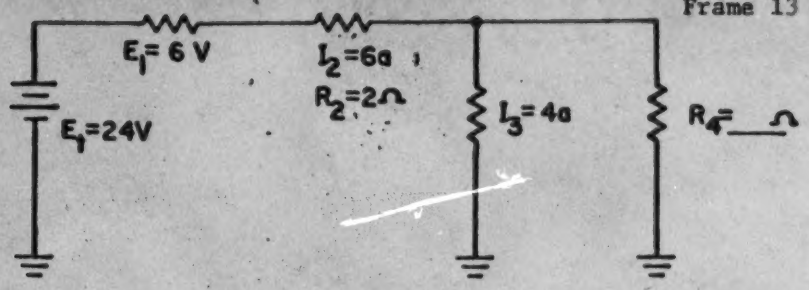
9.


E=2 V
R4= 4Ω
I1= 2a
E2= 6 V
R1 ___ W
R2=3Ω

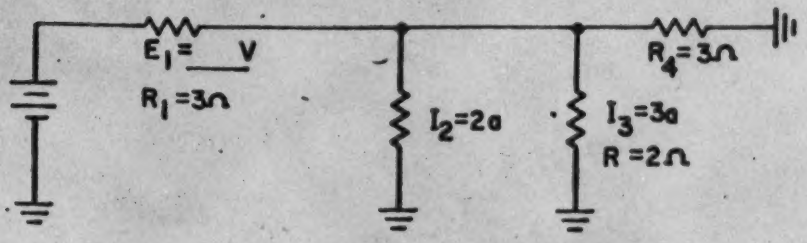
10.


R1=6Ω
R2=3Ω
R4=8Ω
R3=12Ω
R5=4Ω
R1= ___ Ω

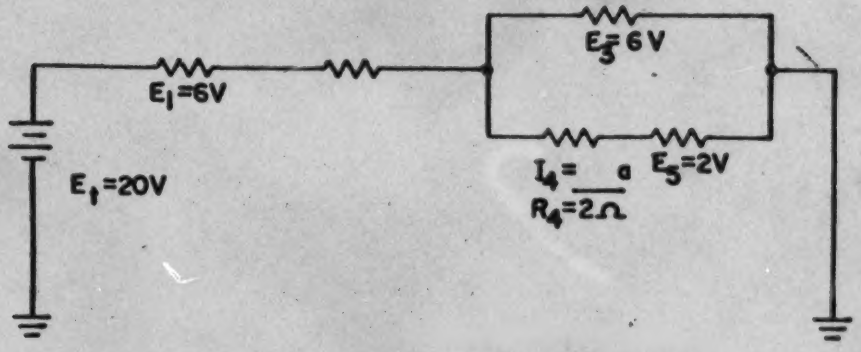
11.



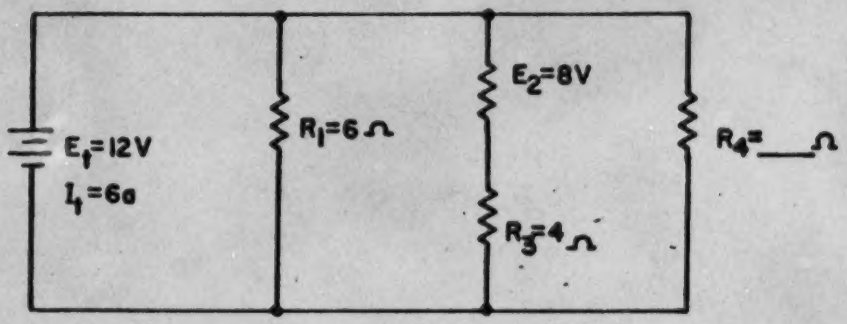
12.



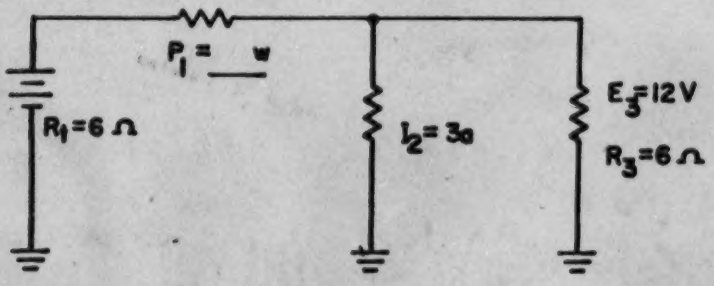
13.



14.



15.



Have the instructor check your answers on the response sheet.

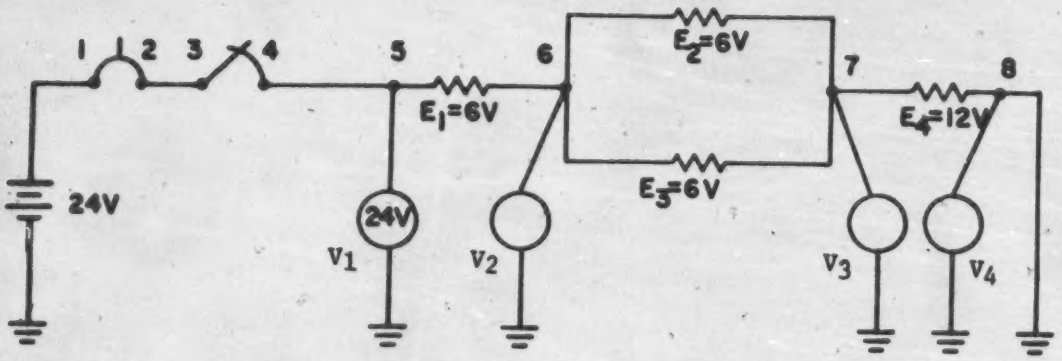
Instructor's Initials _____

The rest of this PT deals with troubleshooting. In order to troubleshoot you must know what the readings are in a good circuit. In the circuit shown the readings at points 1, 2, 3, 4, and 5 should all be 24V. Let's see why! For example, trace a path from the negative side of the battery through the voltmeter (V_1) at point 5 and back to the positive side of the battery. The only item in this path is the voltmeter (V_1). Thus, the voltmeter would read 24V. The same is true for points 1, 2, 3, and 4. Now trace a path from the negative side of the battery through the voltmeter (V_2) connected at point 6 and back to the positive side of the battery. In this path there are two items (the voltmeter and R_1). Since R_1 uses 6V, the voltmeter must read 18V. Fill in 18V for the voltmeter (V_2) at point 6 on the response sheet.

Note: Voltage is a pressure that moves electrons through a resistance. The resistance will use up either all the voltage or part of it in doing its task in the circuit. In this circuit E, used 6 volts of the 24 volts with a remainder of 18 volts of pressure being applied between point 6 and the circuit ground.

Using Kirchhoff's voltage law determine what the meter would read at points 7 and 8. Fill in your answers in the circuit shown on the response sheet.

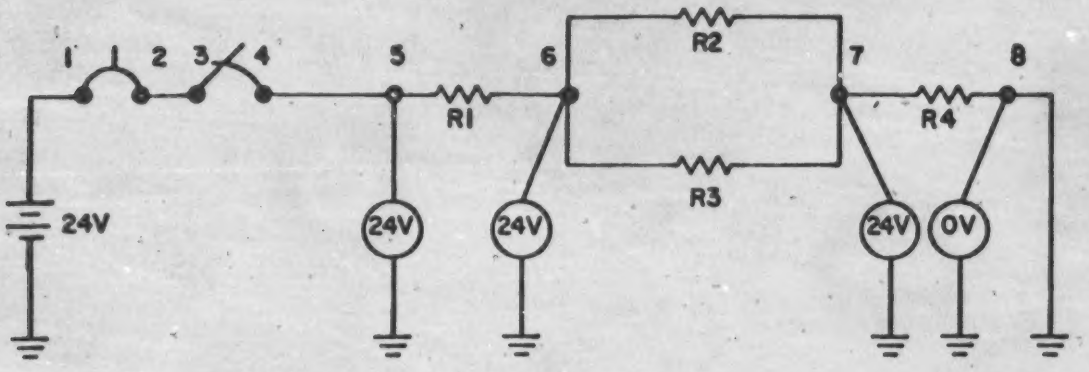
DO NOT MARK IN THIS TEXT



Answers to Frame 14: V_3 = 12V, V_4 = 0V

Frame 15

An open is an incomplete path for current to flow. In the circuit shown we have good readings at points 5 and 8. The readings at point 6 and 7 are abnormal. Even though the readings at points 6 and 7 are abnormal, we know that we have a complete path from the positive battery terminal to point 7 since the voltmeter needle is deflecting. The abnormal reading of 24V at point 7 indicates that the difference in potential across R_4 is 24V and there is an incomplete current path between here and ground. In this case R_4 is open.



Mark the following true statement(s) with a "T" on the response sheet.

____ 1. A voltmeter connected between points 5 and 6 would read 0V.

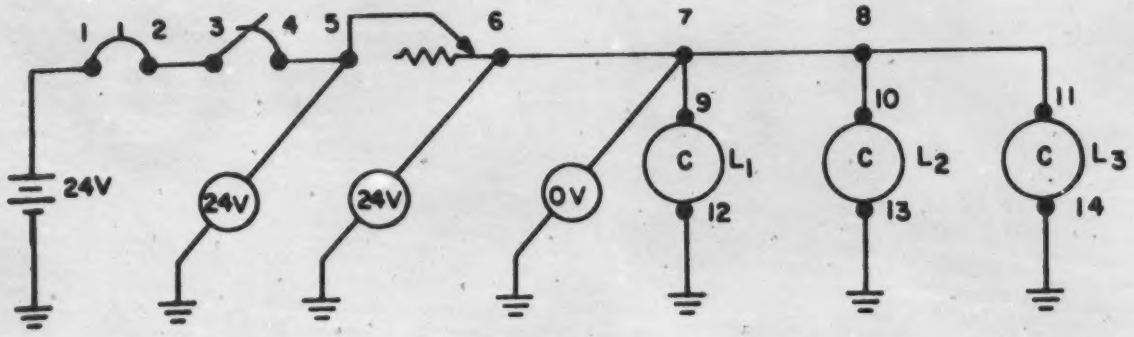
____ 2. A voltmeter connected between points 6 and 7 would read 24V.

____ 3. A voltmeter connected between points 7 and 8 would read 24V.

Answers to Frame 15: 1. T, 2. ___, 3. T

Frame 16

In the circuit shown all lamps* are inoperative. Since none of the lamps work, the open would be between points 1 and 7. If the open was anywhere else in the circuit, one or more of the lamps would be lit. The 24V reading at point 6 indicates that there is a complete path to point 6. The 0V reading at point 7 indicates that there is an open between points 6 and 7.



For each of the following malfunction indications, indicate on the blank the possible open components that could be the cause. Write your answers on the response sheet. Number 1 has been done as an example (see your response sheet for the answers).

1. L_1 is inoperative. _____
2. L_2 is inoperative. _____
3. L_3 is inoperative. _____
4. L_2 and L_3 are inoperative. _____

*Note: Lamps in this text are identified by the letters L_1, L_2, L_3, etc., or, by an applicable symbol. Those drawn as a simple circle with a letter inside denote its color; e.g., C for clear, R for red, etc.

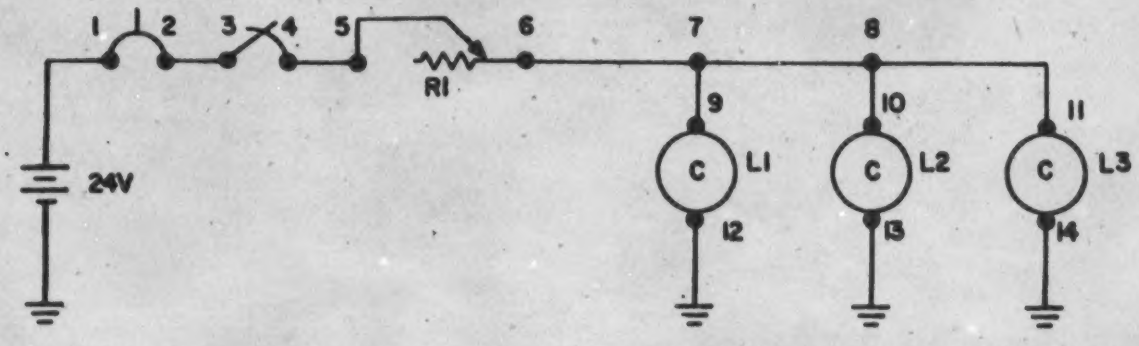
Answers to Frame 16: 2. 8 & 10, 10 & 13 (L_2), 13 & ground

3. 8 & 11, 11 & 14 (L_3), 14 & ground 4. 7 & 8

Frame 17

Before taking readings or analyzing readings in a circuit you should consider the possible components that could cause the circuit malfunction.

Using the circuit shown, determine the type of trouble and the faulty component for each of the following problems. Put your answers on the appropriate blanks on the response sheet. The first one has been done for you to show you how to do it. Look at the answer on your response sheet and compare it to the circuit.



1. L_1 is inoperative. A voltmeter connected between point 7 and ground reads 24V. A voltmeter connected between point 9 and ground reads 0V.

2. L_2 and L_3 are inoperative. A voltmeter connected from 8 to ground reads 0V.

3. All lamps are inoperative. A voltmeter connected from 5 to ground reads 24V. A voltmeter connected from 6 to ground reads 0V.

4. All lamps are inoperative. A voltmeter connected from points 1, 2, and 3 to ground reads 24V. A voltmeter connected from point 4 to ground reads 0V.

5. L_3 is inoperative. A voltmeter connected from 8, 11, and 14 to ground reads 24V.

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Answers to Frame 17: 2. open 7 & 8, 3. open 5 & 6 (R_1),
4. open 3 & 4 5. open 14 & ground

Frame 18

The normal circuit readings are given in figure 1 below. From these readings you should see that the voltage drop across R_1 is equal to 6V. (24 - 18 = 6V.) The drop across each lamp is 18V. (18 - 0 = 18V.)

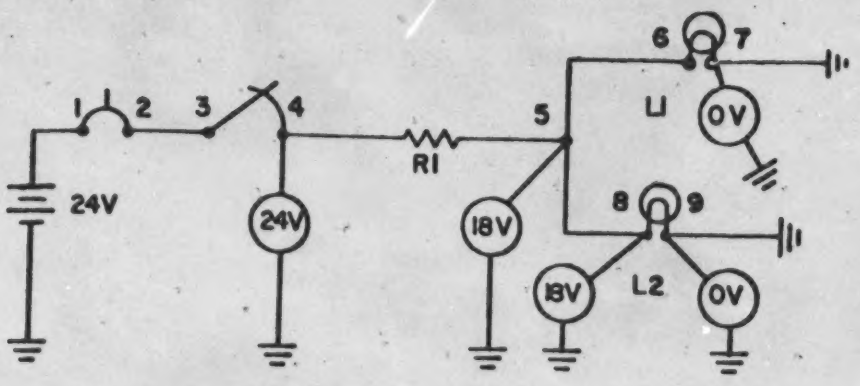


Figure 1.

Now let's see what the readings would be if L_2 burned out. This is shown in figure 2. Since there is still a complete path in the circuit, there will be current flowing through L_1 and R_1. Since there is current flowing through R_1, there will be a voltage drop across it. Thus, even though L_2 is open, the difference in potential across it will not be equal to the applied voltage (24V). If you had not been told that L_2 was open, you could still determine this from the readings given. Since there is a difference in potential across the L_2 and it is not lit, the lamp must be open.

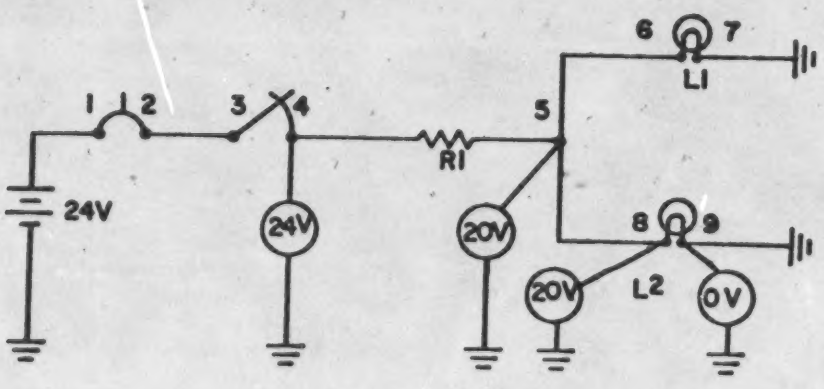


Figure 2.

Mark the correct answer for each of the following questions on the response sheet.

_____ 1. If R_1 was open in figure 1, the voltmeter would read 0V at point

a. 1

b. 2

c. 3

d. 5

_____ 2. If the wire between points 5 and 8 was open in figure 1, the voltmeter would read 0V at point

a. 1

b. 3

c. 5

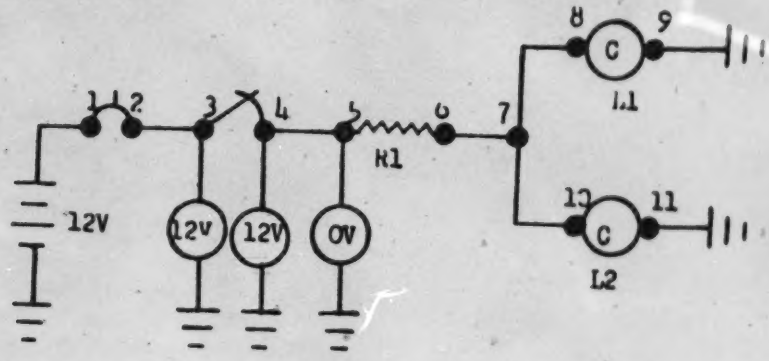
d. 8

Answers to Frame 18: 1. d, 2. d

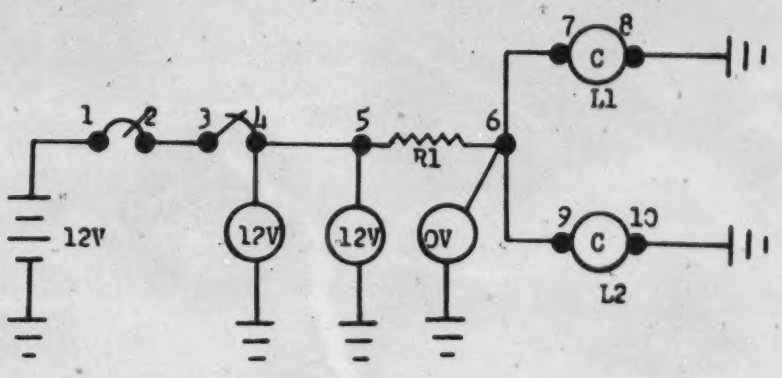
Frame 19

Analyze the meter readings and circuit indications in each of the following circuits. On the blank provided by each circuit list the type of trouble and the faulty component on the response sheet. The first one was done for you as an example.

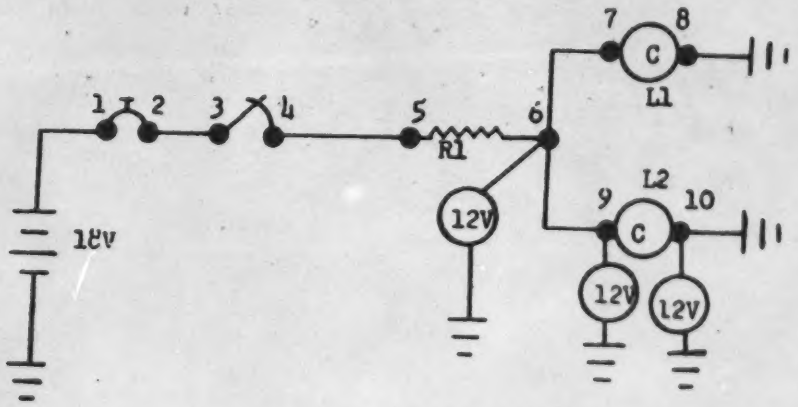
1. Both lamps inoperative. _____



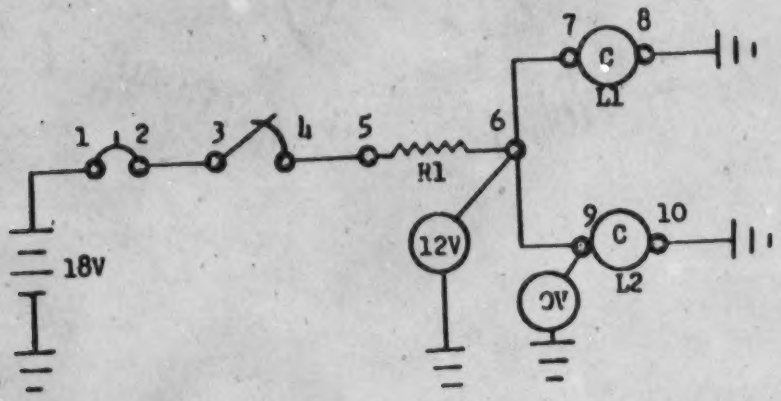
2. Both lamps inoperative _____



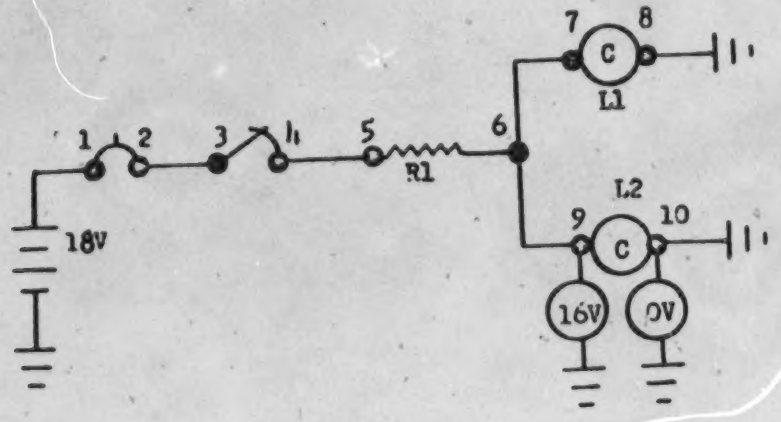
3. L_2 is inoperative. _____



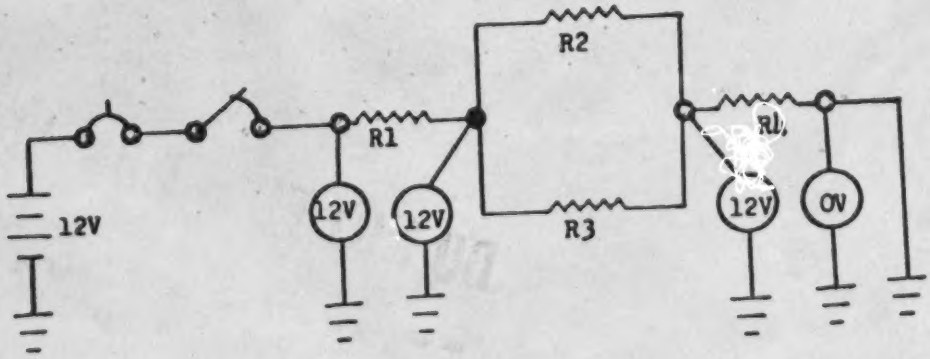
4. L_2 is inoperative. _____



5. L_2 is inoperative. _____



6. _____

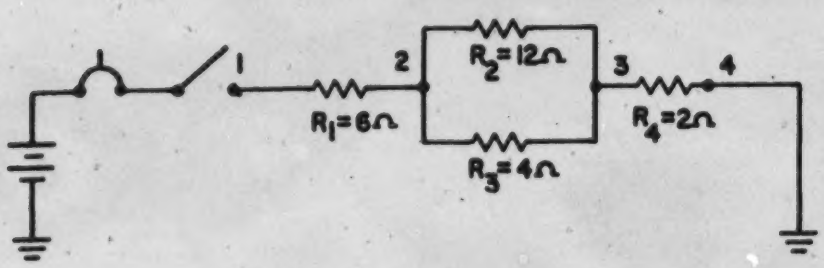


729

Answers to Frame 19: 2. open 5-6 (R_1), 3. open 10 to ground, 4. open 6-9
5. open 9-10 (L_2) 6. open R_4

Frame 20

An open can also be located with an ohmmeter. The ohmmeter has its own source of power and should not be used in a live circuit. Before we use an ohmmeter for troubleshooting let's see what readings the ohmmeter would indicate in a normal circuit. We will use the circuit shown below. An ohmmeter connected from point 4 to ground should read 0 ohms because the resistance of the ground wire will be 0 ohms. An ohmmeter connected from point 3 to ground should read 2 ohms, the resistance of R_4. What should the ohmmeter read when connected at point 2? If you said 5 ohms, you are correct. When the ohmmeter is connected to point 2 it reads through R_2, R_3, and R_4. Since R_2 and R_3 are in parallel with each other we need to compute their series equivalent resistance. Using the product-over-the-sum formula we find this to be 3 ohms. Add this value to the value of R_4 and we find that the ohmmeter would read 5 ohms at point 2.



Mark the correct statement(s) with a "T" on the response sheet.

_____ 1. An ohmmeter connected from point 1 to ground would read 11 ohms.

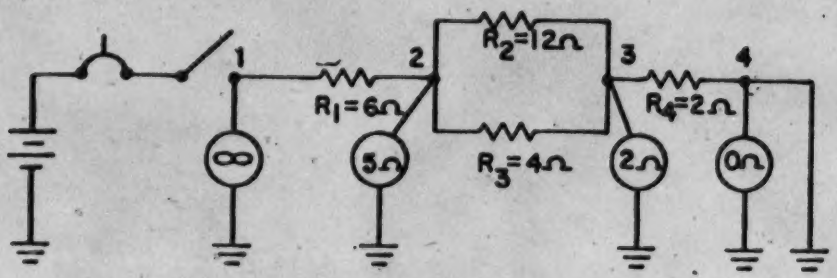
_____ 2. An ohmmeter connected from point 1 to point 2 would read 11 ohms.

_____ 3. An ohmmeter connected from point 2 to point 3 would read 16 ohms.

Answers to Frame 20: 1. T, 2. ___, 3. ___

Frame 21

Let's get some practice troubleshooting with an ohmmeter. In the circuit shown below we have given you ohmmeter readings at different points in the circuit. In order to have needle deflection, you must have current flowing through the movement. If no current is flowing through the movement, the needle will indicate infinity (∞). A reading of 0 ohms at point 4 indicates that the ground wire is good. The readings at point 3 and point 2 indicate that there is a complete path to point 2. When the ohmmeter is connected to point 1, the needle doesn't deflect. This indicates that no current is flowing through the ohmmeter when it is connected to point 1. Since we had a complete path up to point 2 and didn't have one up to point 1, there must be an open between points 1 and 2. In this case R_1 is open.



Mark the correct answer for each of the following questions on the response sheet.

_____ 1. If an ohmmeter was connected around R_1 (points 1 and 2), the ohmmeter would read infinity (∞) indicating that R_1 is

a. closed.

b. open.

_____ 2. If R_4 was open, an ohmmeter connected from point 3 to point 4 would read

a. 0 ohm.

b. infinity.

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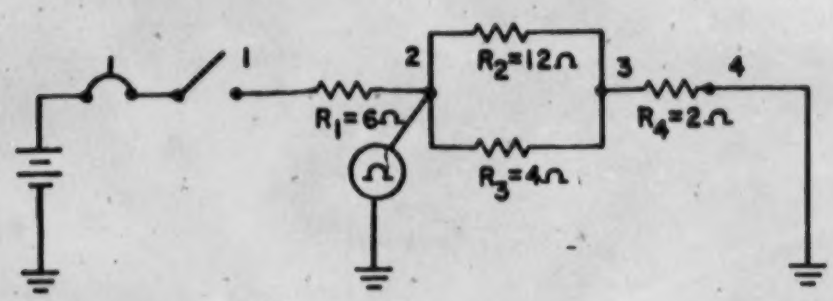
Answers to Frame 21: 1. B, 2. B, 3. ___

Frame 22

We will use the same circuit that we used in the last two frames. Let's see what the reading at point 2 would be if R_2 became open. With R_2 open, the ohmmeter would read through R_3 and R_4. Since R_2 is open, R_3 and R_4 are connected in series with each other and the ohmmeter will read 6 ohms (4 + 2).



Mark the following true statement(s) with a "T" on the response sheet.

____ 1. If R_3 had been open instead of R_2, the ohmmeter at point 2 would read 14 ohms.

____ 2. If R_3 had been open instead of R_2, an ohmmeter at point 1 would read 6 ohms.

Answers to Frame 22: 1. T, 2. ___

Frame 23

In some cases you will need to isolate the branches of the parallel part in order to determine the faulty component. For example, in the circuit shown below we have a 6 ohm reading at point 5. This indicates that the ohmmeter is reading through only one of the parallel branches and means one of the parallel branches has an open in it.

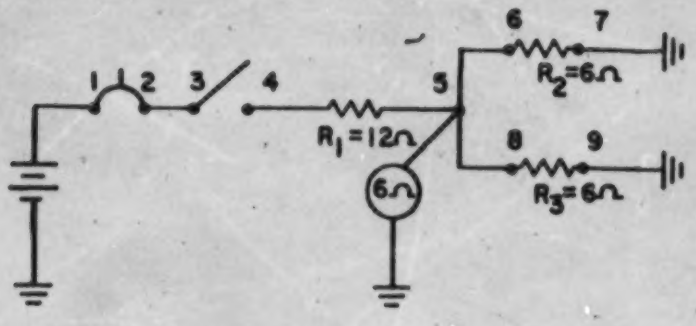


Figure 1.

To isolate the branches we would need to only disconnect one of the branches. This is shown below. We took readings at the points indicated. The ground wire for R_3 is good as indicated by the 0 ohm reading. The infinity reading at point 8 indicates that R_3 is open.

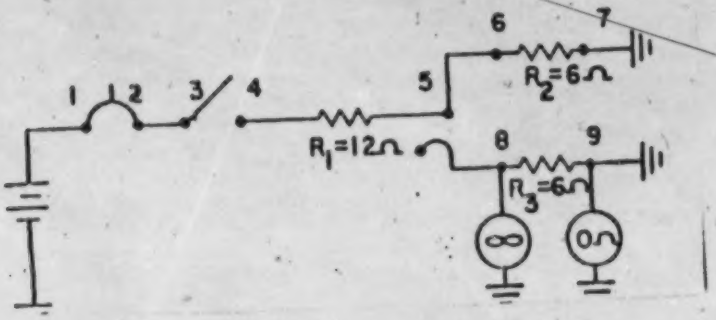


Figure 2.

Mark the following true statement(s) with a "T" on the response sheet.

_____ 1. An ohmmeter connected around a good ground wire should read 0 ohms.

_____ 2. An ohmmeter connected around an open will read ∞.

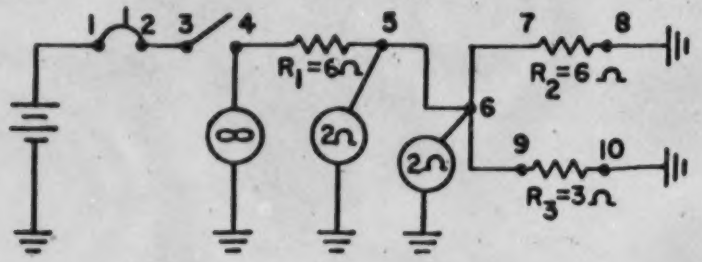
_____ 3. An ohmmeter connected at point 4 in figure 1 would read 12 ohms.

Answers to Frame 23: 1. T, 2. T, 3. ___

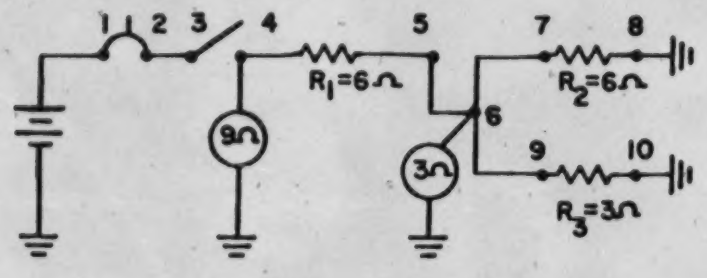
Frame 24

Analyze the meter readings in each of the following circuits. On the blanks provided by each circuit list the type of trouble and the faulty component. The first one has been done for you to show you how. Look at the answer on the response sheet and compare it to the meter readings.

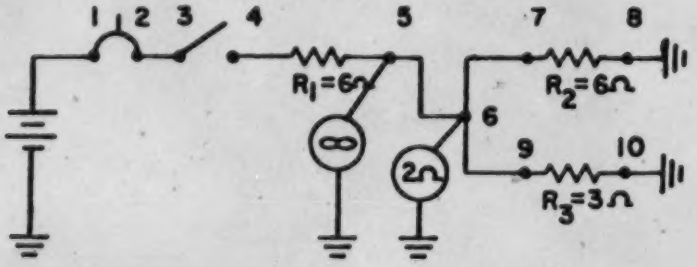
1. _____



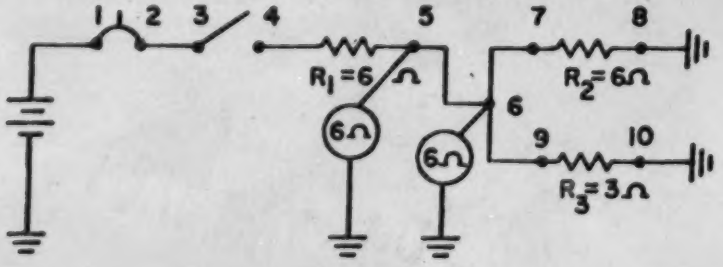
2. _____



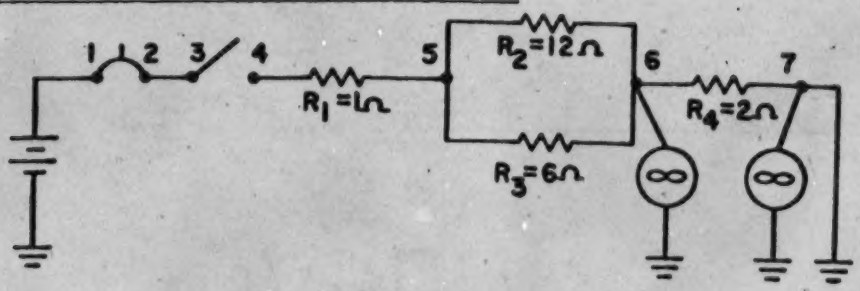
3. _____



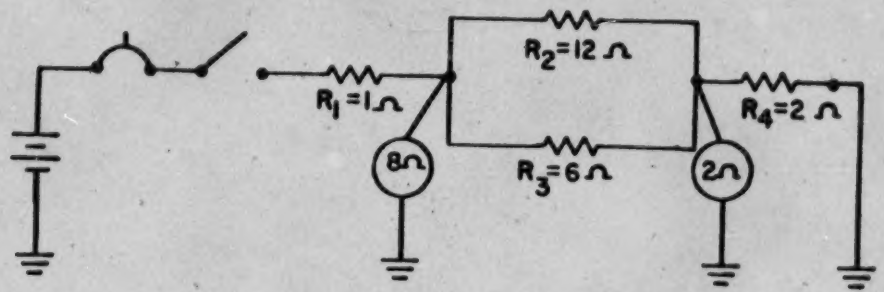
4. _____



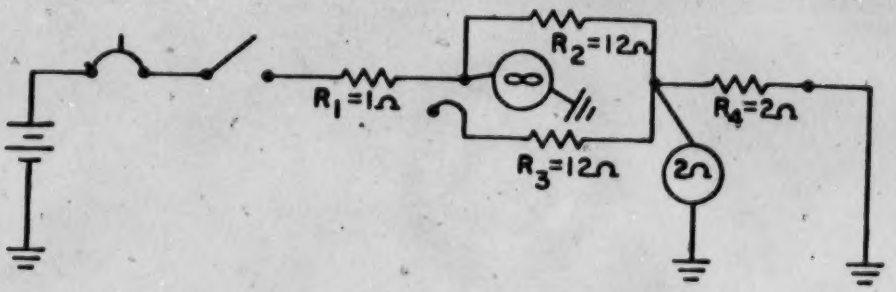
5. _____


1
2
3
4
5
6
7
R_1=1Ω
R_2=12Ω
R_3=6Ω
R_4=2Ω
∞
∞

6. _____


R_1=1Ω
R_2=12Ω
R_3=6Ω
R_4=2Ω
8Ω
2Ω

7. _____


R_1=1Ω
R_2=12Ω
R_3=12Ω
R_4=2Ω
∞
2Ω

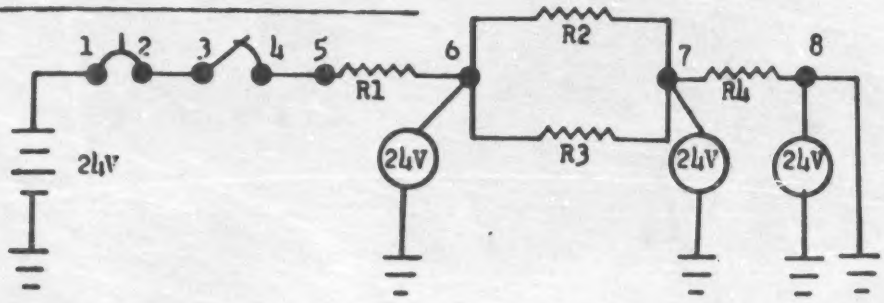
735

Answers to Frame 24: 2. open 6-7, 7-8, or 8 to ground, 3. open 5-6, 4. open 6-9, 9-10 or 10 to ground 5. open 7 to ground, 6. open R_2, 7. open R_2

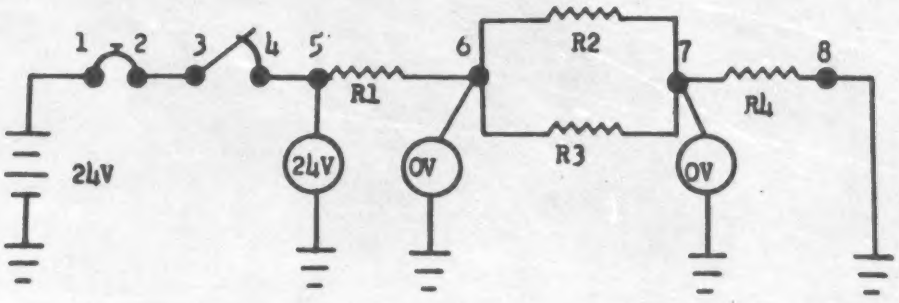
Frame 25

Analyze the meter readings and circuit indications in each of the following circuits. Using the blank on the response sheet for each circuit, list the type of trouble and faulty component. Have your instructor check your work when you have finished all nine problems.

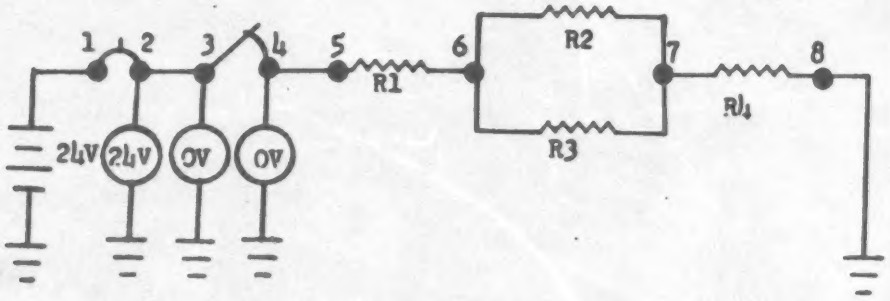
1. _____



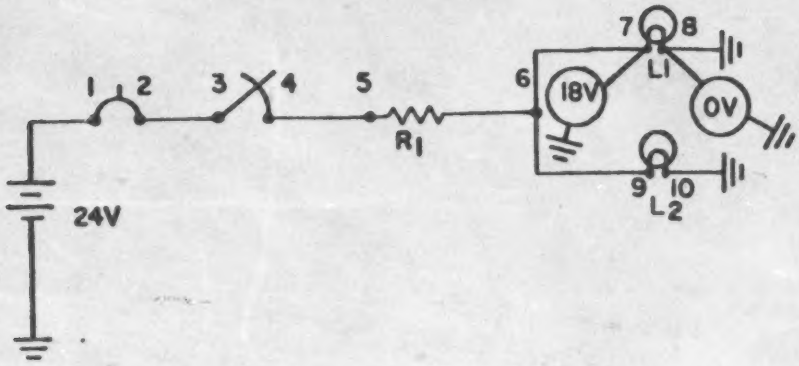
2. _____



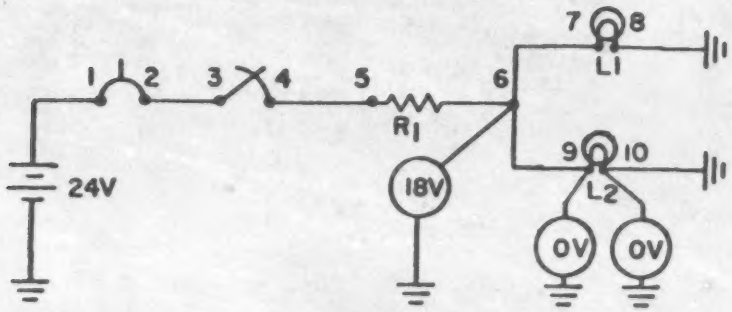
3. _____



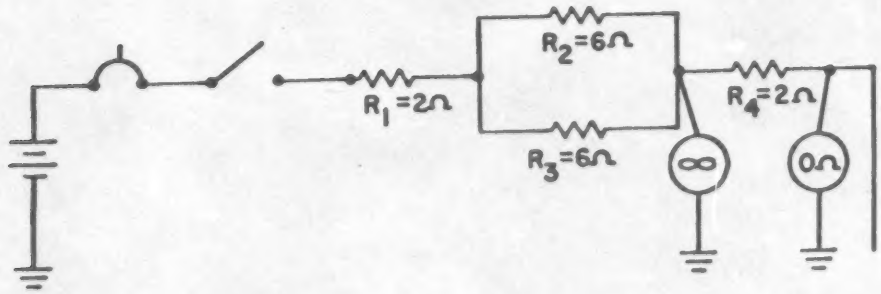
4. L_1 is inoperative. _____



5. L_2 is inoperative. _____

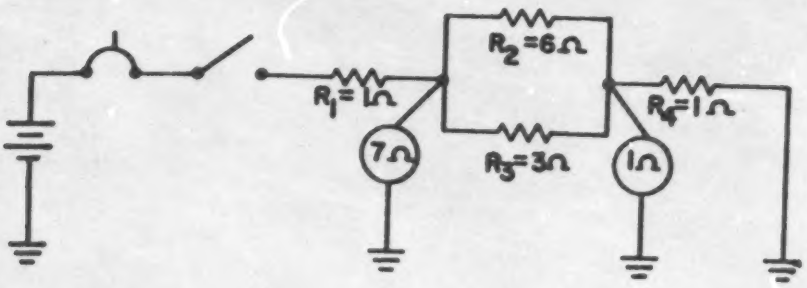


6. _____ _____

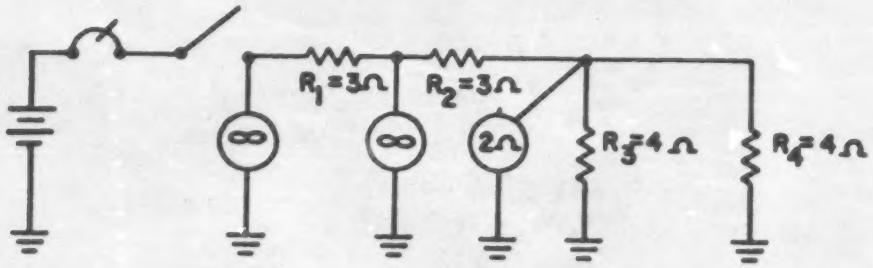


Frame 25 (Cont'd)

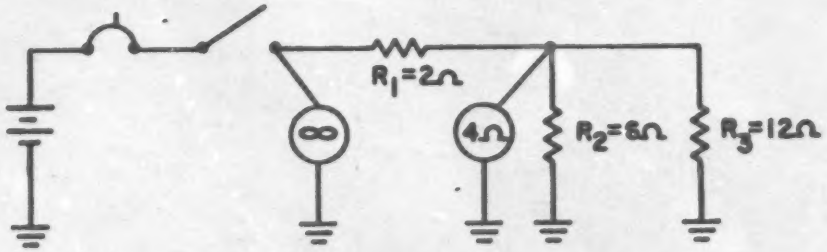
7. _____



8. _____



9. _____

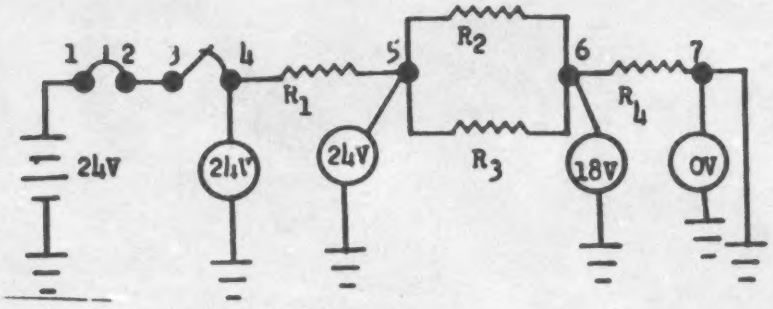


Have the instructor check your answers on the response sheet.

Instructor's Initials _____

Frame 26

A short circuit is an accidental path of low resistance which passes an abnormal amount of current. Each load unit in a circuit should drop some of the applied voltage. If the load unit is shorted the current will bypass the load unit and flow through the low resistance path. With no current flowing through the load unit, it will not have any voltage dropped across it. In the circuit below we have given you readings at different points. Which resistor does not have a difference in potential across it? If you said R_1, you are correct. Let's see why! The potential at point 4 is 24V and the potential at point 5 is 24V. Thus, there is no difference in potential across R_1. Look at the rest of the circuit. R_2 and R_3 are dropping 6V. R_4 is dropping 18V. There is current flowing in the circuit. Since there is no difference in potential across R_1 and there is current flowing in the circuit, R_1 is shorted.



Mark the correct answer for each of the following questions on the response sheet.

_____ 1. A voltmeter connected between points 4 and 5 would read

a. 0 volts.
b. 24 volts.

_____ 2. A voltmeter connected between points 5 and 6 would read

a. 24 volts.
b. 18 volts.
c. 6 volts.

_____ 3. The difference in potential across a shorted resistor is

a. 24 volts.
b. 18 volts.
c. 6 volts.
d. 0 volts.

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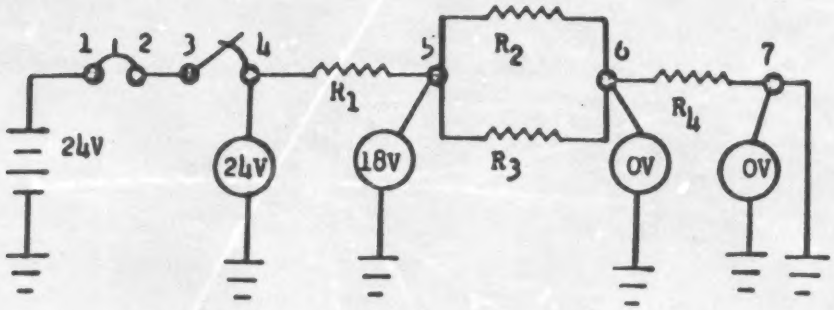
Answers to Frame 26: 1. a, 2. c, 3. d

Frame 27

In the circuit shown we have given you readings at different points. Let's find the faulty component. The difference in potential across R_1 is 6V. The difference in potential across the parallel part (R_2 and R_3) is 18V. The difference in potential across R_4 is 0V making the resistance of R_4 0 ohms. Since there is voltage dropped on R_1, R_2, and R_3, we know there is current flowing through them. Since there is current flowing in the circuit, but no voltage is dropped across R_4, R_4 must be shorted.



Mark the following true statement(s) with a "T" on the response sheet.

_____ 1. The difference in potential across a shorted resistor is 0V.

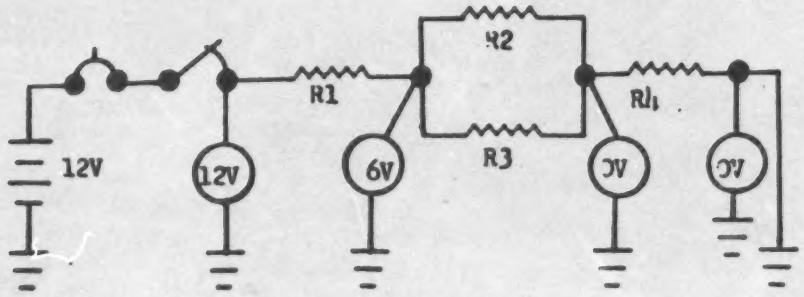
_____ 2. A voltmeter connected between points 4 and 6 would read 24V.

Answers to Frame 27: 1. T, 2. T

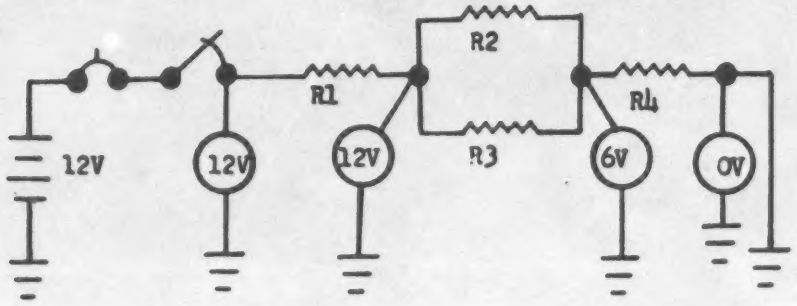
Frame 28

Analyze the meter readings in each of the following circuits. Using the blank on the response sheet provided for each circuit, list the type of trouble and the faulty component. The first one has been done for you to show how you should record your answer. Use the answer listed on the response sheet and determine why it is right by analyzing the meter readings.

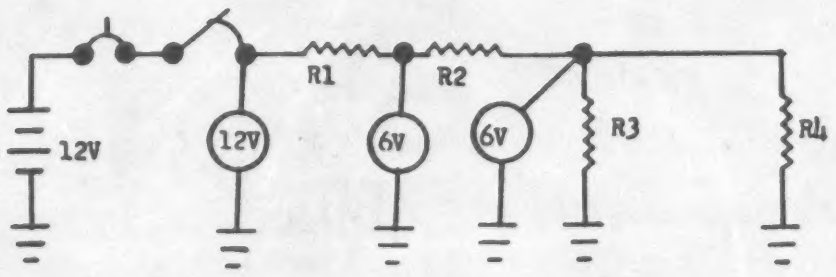
1. _____



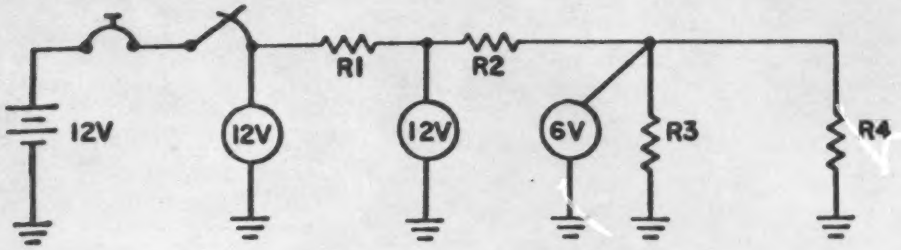
2. _____



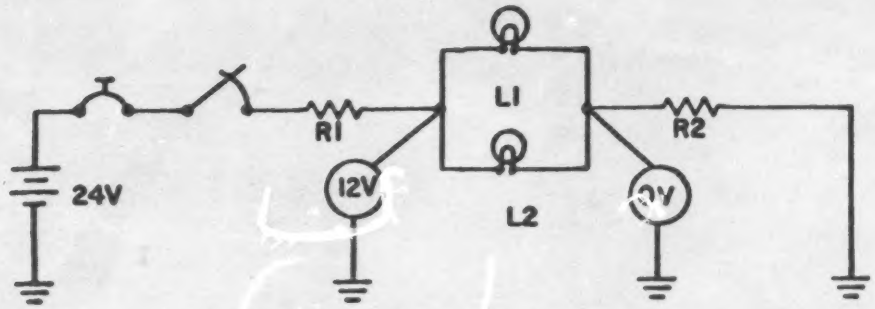
3. _____



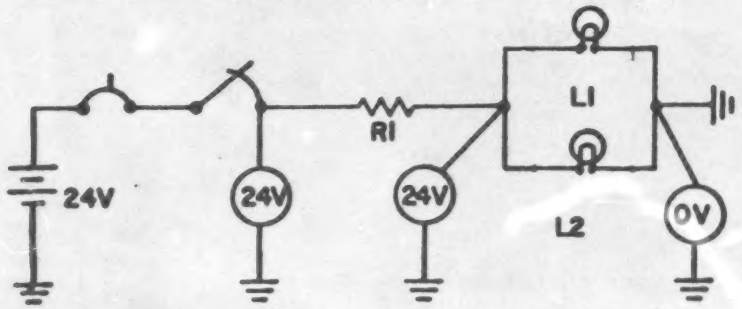
4. _____


12V
12V
R1
12V
R2
6V
R3
R4

5. _____


24V
R1
L1
12V
L2
R2

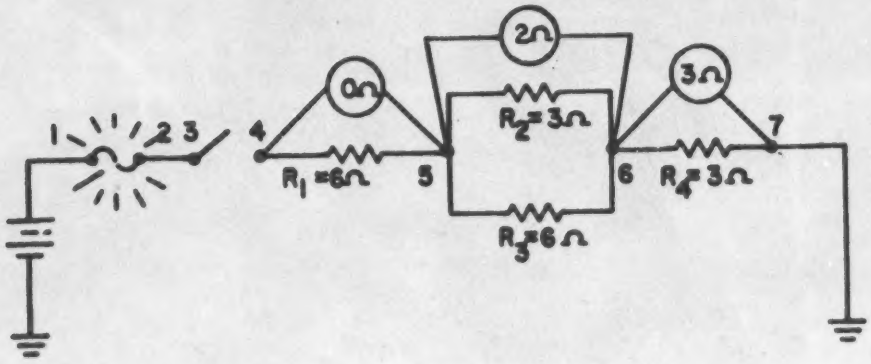
6. _____


24V
24V
R1
L1
24V
L2
0V

Answers to Frame 28: 2. short R_1, 3. short R_2, 4. short R_1, 5. short R_2, 6. short R_1

Frame 29

Many times a short circuit will cause the fuse to blow. When this happens you will need to use an ohmmeter to find the faulty component. Since a shorted resistor has a 0 ohm resistance path, an ohmmeter connected around a shorted resistor will read 0 ohms. In the circuit below we have taken ohmmeter readings across each resistor. Which resistor is shorted? R_1 is shorted since the ohmmeter connected around it reads 0 ohms.



Mark the following true statement(s) with a "T" on the response sheet.

_____ 1. An ohmmeter connected from point 7 to ground should read 3 ohms.

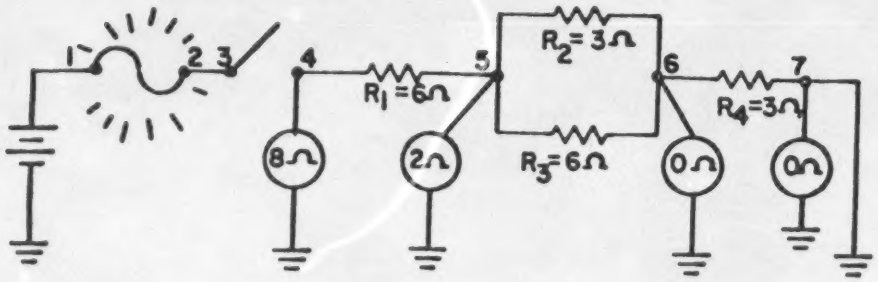
_____ 2. An ohmmeter connected from point 5 to ground should read 12 ohms.

_____ 3. An ohmmeter connected from point 4 to ground would read the same as one connected from point 5 to ground if R_1 was shorted.

Answers to Frame 29: 1. ___, 2. ___, 3. T

Frame 30

In the circuit shown we need to find why the fuse has blown. The reading at point 7 should be 0 ohms since we are just measuring the resistance of the ground wire. The reading at point 6 should be 3 ohms since we are just checking the resistance of the ground wire and R_4. However, the reading at point 6 is 0 ohms. This indicates that R_4 is shorted.



Mark the correct answer for each of the following questions on the response sheet.

_____ 1. You probably have a short somewhere in the circuit if the

a. switch closes.

b. fuse blows.

c. ground opens.

_____ 2. An ohmmeter connected between points 4 and 5 read

a. 0 ohms.

b. 3 ohms.

c. 6 ohms.

_____ 3. An ohmmeter connected between points 5 and 6 read

a. 2 ohms.

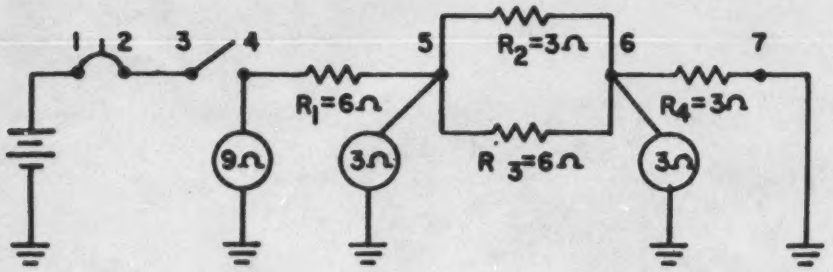
b. 3 ohms.

c. 6 ohms.

Answers to Frame 30: 1. b, 2. c, 3. a

Frame 31

The reading at point 6 indicates that R_4 is good. What does the reading of 3 ohms at point 5 indicate? If you said a short in R_2 or R_3, you are correct. Let's see why! If either R_2 or R_3 is shorted, they are in effect both shorted as the resistance of the parallel part would be 0Ω. In order to find which resistor is shorted, we would need to isolate R_2 and R_3.



Mark the following true statement(s) with a "T" on the response sheet.

_____ 1. An ohmmeter connected between points 5 and 6 would read 0 ohms.

_____ 2. An ohmmeter connected from point 7 to ground should read 0 ohms.

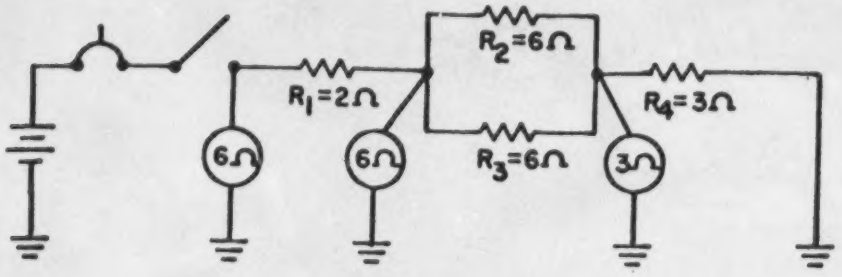
745

Answers to Frame 31: 1. T 2. T

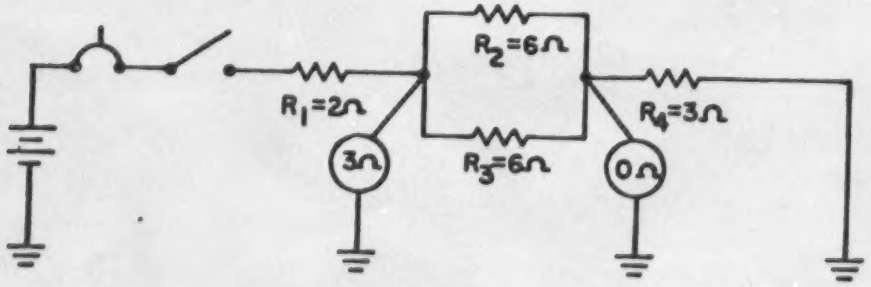
Frame 32

Analyze the meter readings in each of the following circuits. Using the blank on the response sheet provided for each circuit list the type of trouble and the faulty components. The first one has been done for you to show you how to record your answers.

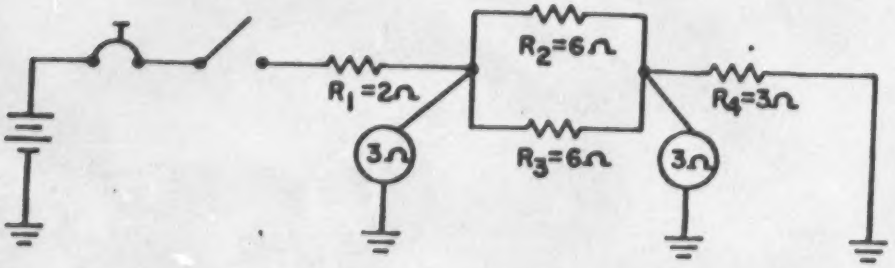
1. _____



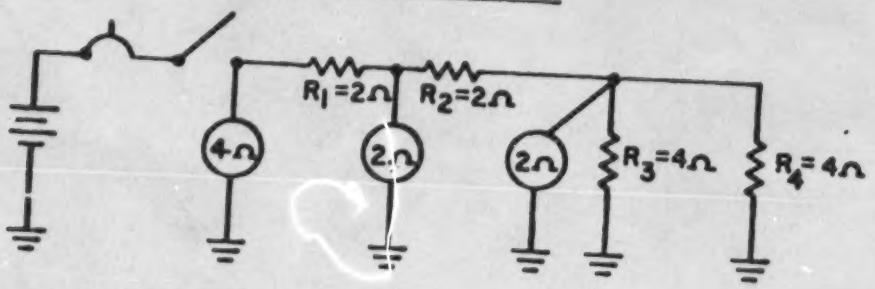
2. _____



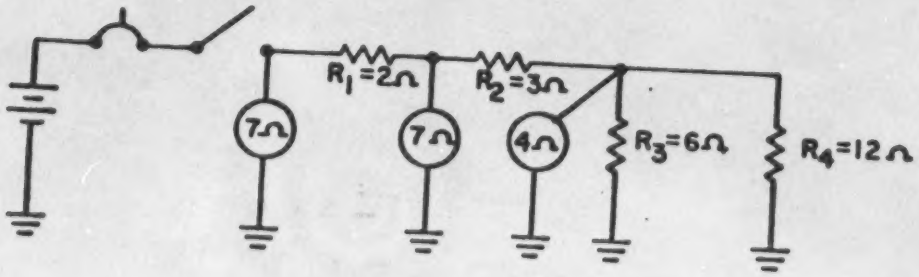
3. _____



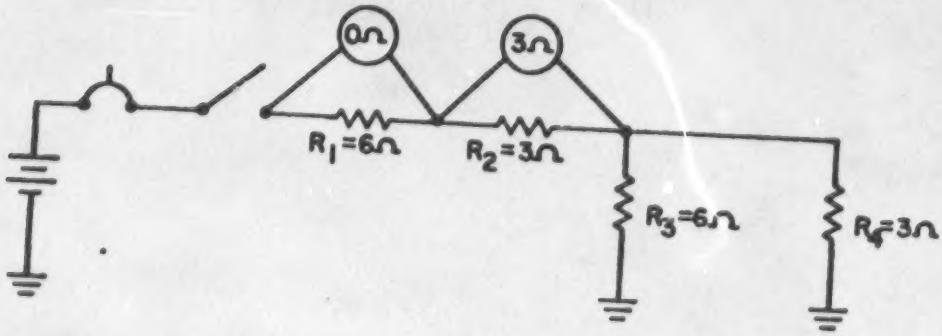
4. _____


R1=2Ω
R2=2Ω
4Ω
2Ω
2Ω
R3=4Ω
R4=4Ω

5. _____


R1=2Ω
R2=3Ω
7Ω
7Ω
4Ω
R3=6Ω
R4=12Ω

6. _____

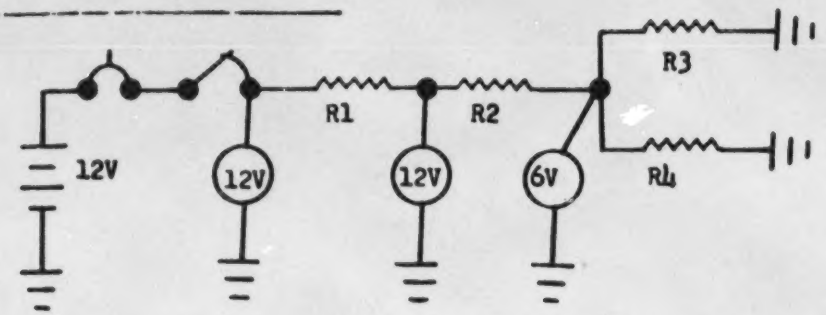

0Ω
3Ω
R1=6Ω
R2=3Ω
R3=6Ω
R4=3Ω

Answers to Frame 32: 2. short R_4, 3. short R_2 or R_3, 4. short R_2, 5. short R_1, 6. short R_1

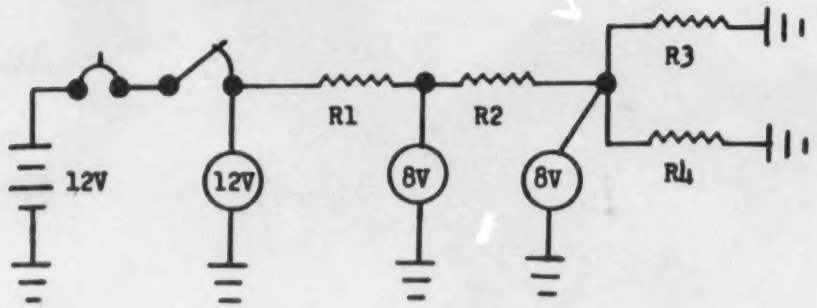
Frame 33

Analyze the meter readings in each of the following circuits. Using the blank on the response sheet provided for each circuit, list the type of trouble and the faulty component.

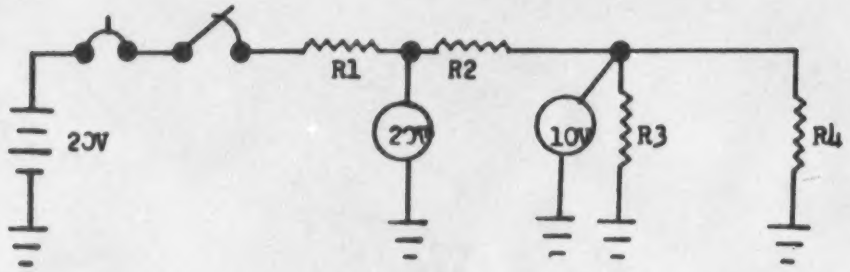
1. _____



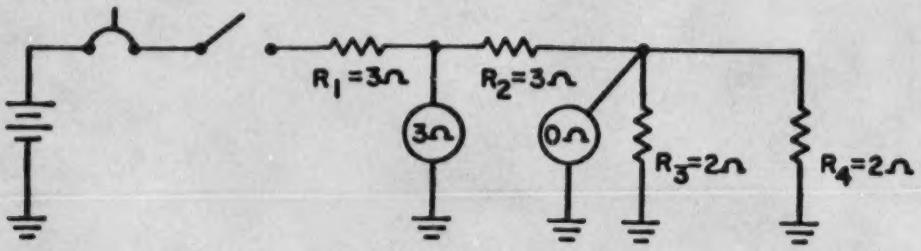
2. _____



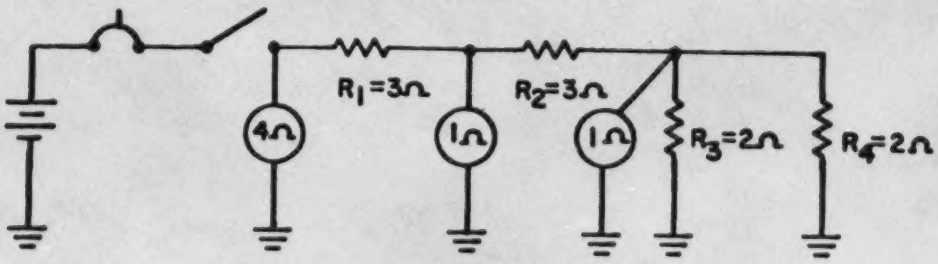
3. _____



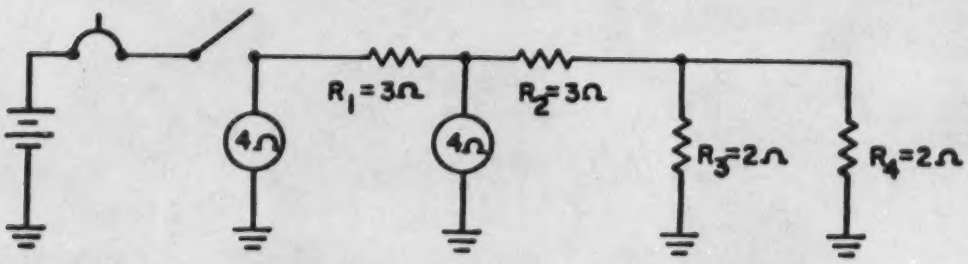
4. _____



5. _____



6. _____



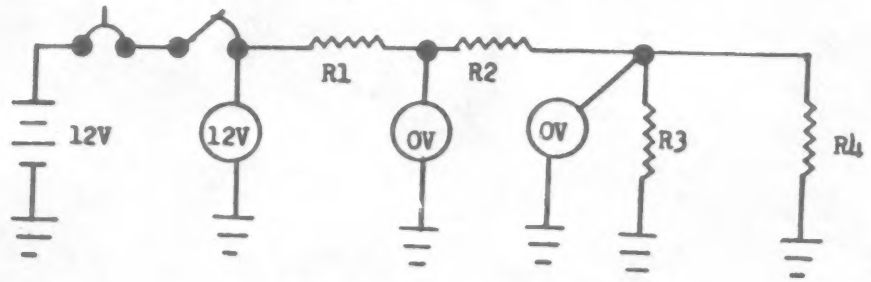
Have the instructor check your answers to this frame on the response sheet.

INSTRUCTOR's Initials _____

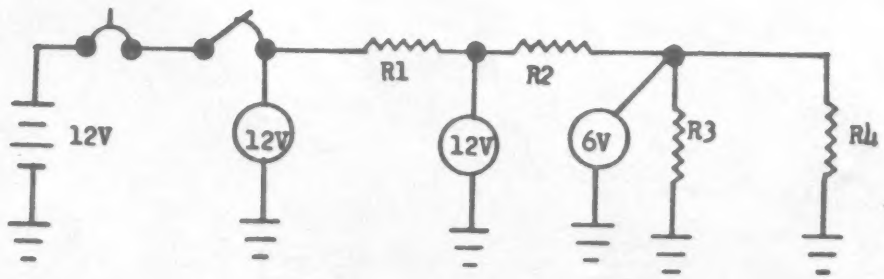
749
Frame 34

Analyze the meter readings in each of the following circuits. Using the blank on the response sheet provided for circuit list the type of trouble and the faulty component. The first one has been done to show you how to record your answers.

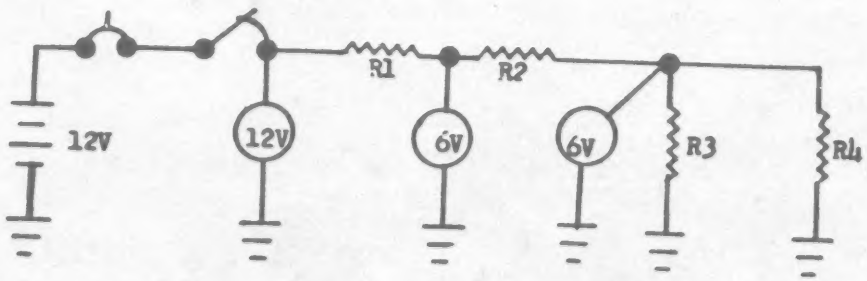
1. _____



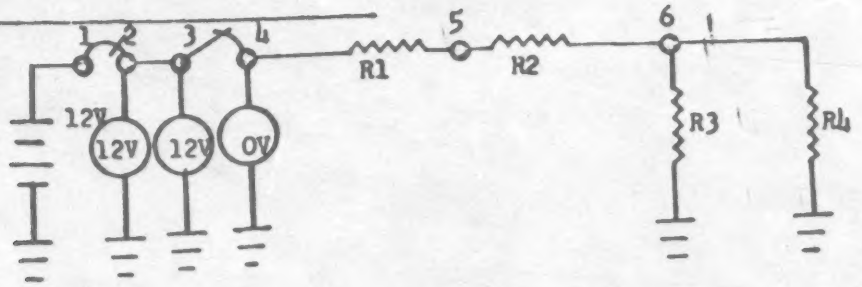
2. _____



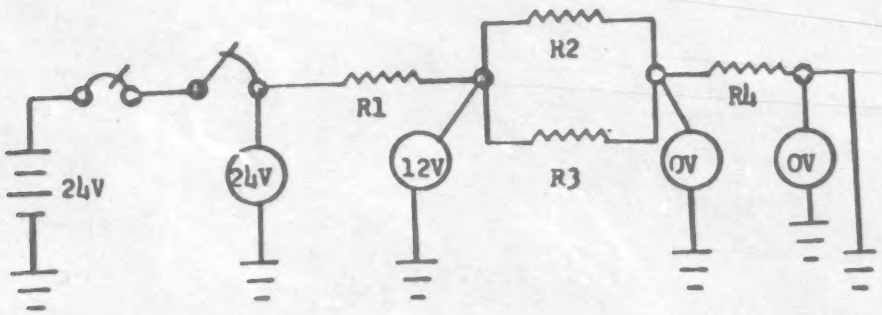
3. _____



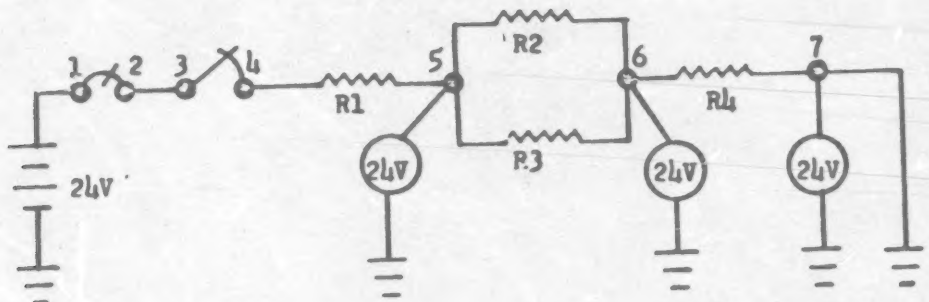
4. _____


1
2
3
4
5
6
R1
R2
R3
R4
12V
12V
12V
0V

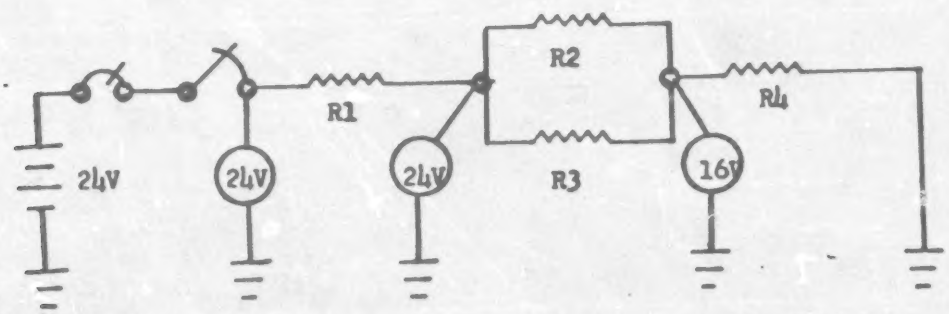
5. _____


R2
R1
R4
24V
24V
12V
R3
0V
0V

6. _____


1
2
3
4
5
R2
6
7
R1
R4
24V
24V
R3
24V
24V

7. _____


R2
R1
R4
24V
24V
24V
R3
16V

751

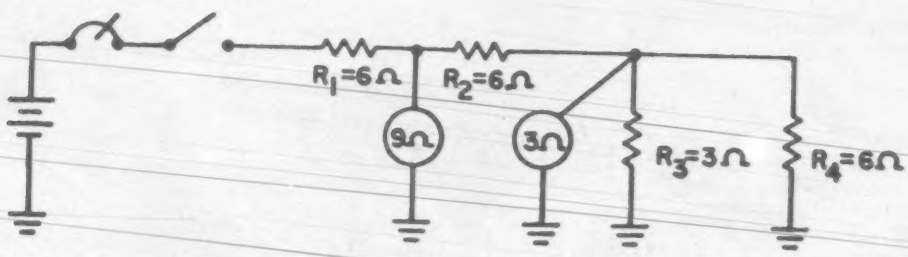
Answers to Frame 34: 2. short R_1, 3. short R_2, 4. open 3-4 switch

5. short R_4 6. open 7-ground 7. short R_1

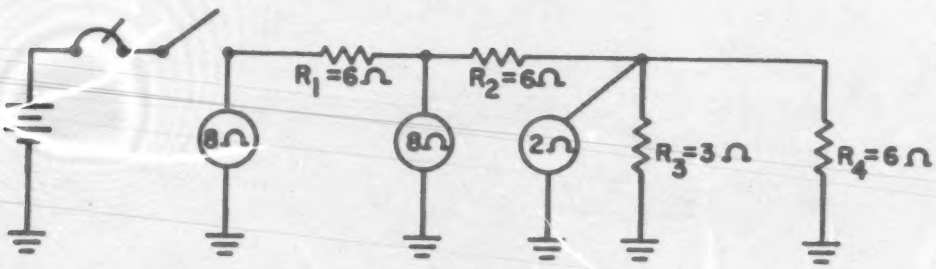
Frame 35

Analyze the meter readings in each of the following circuits. Using the blank on the response sheet provided for each circuit list the type of trouble and the faulty component. The first one has been done to show you how to record your answers.

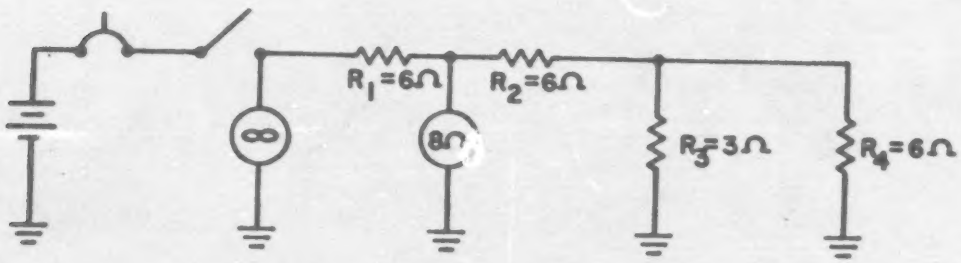
1. _____



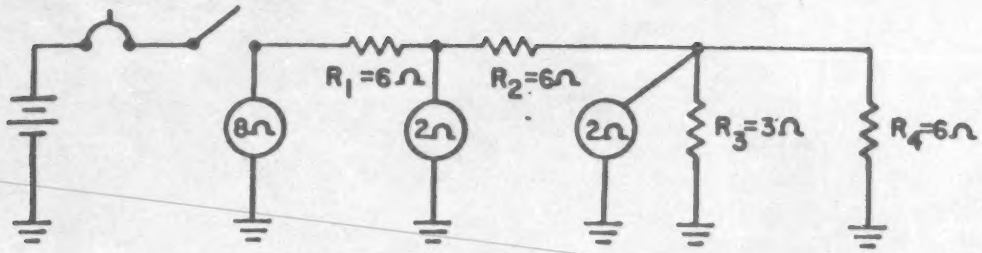
2. _____



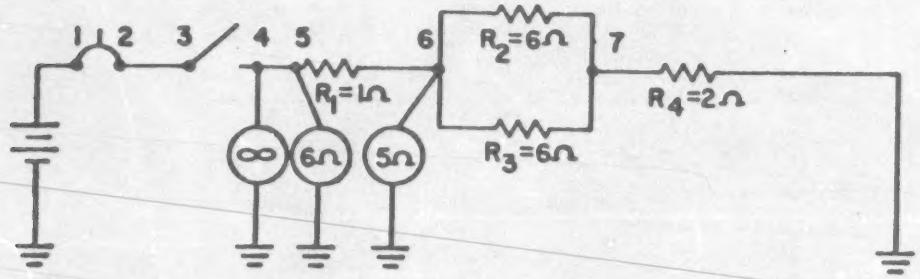
3. _____



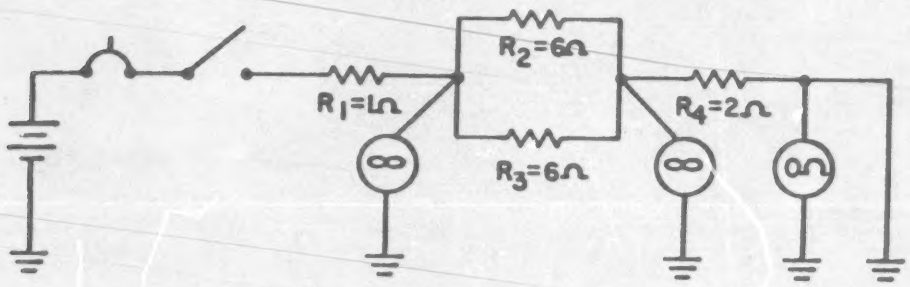
4. _____


R1=6Ω
R2=6Ω
8Ω
2Ω
2Ω
R3=3Ω
R4=6Ω

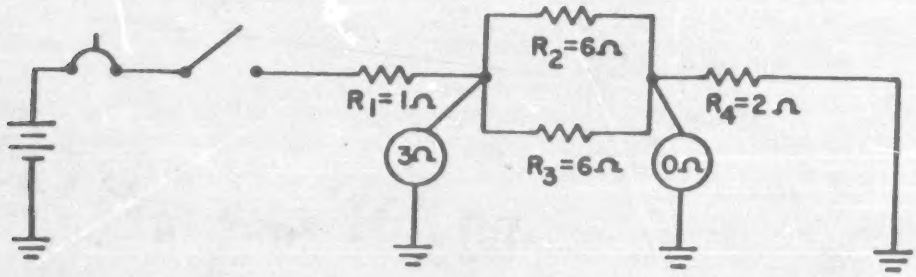
5. _____


1
2
3
4
5
6
7
R2=6Ω
R1=1Ω
R4=2Ω
∞
6Ω
5Ω
R3=6Ω

6. _____


R2=6Ω
R1=1Ω
R4=2Ω
∞
R3=6Ω
∞
5Ω

7. _____

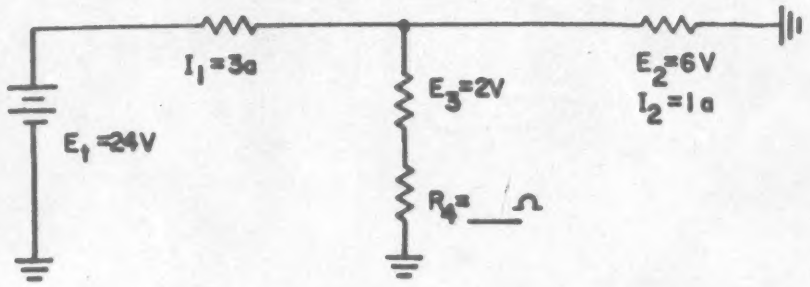

R2=6Ω
R1=1Ω
R4=2Ω
3Ω
R3=6Ω
0Ω

Answers to Frame 35: 2. short R_1, 3. open R_1, 4. short R_2, 5. open 4-5 6. open R_4, 7. short R_4

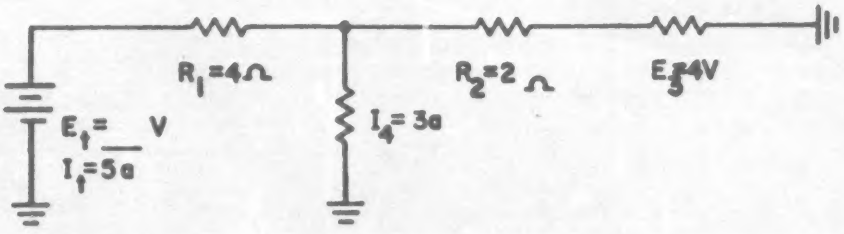
Frame 36

Solve each of the following problems for the indicated unknown. Put your answers on the appropriate blanks on the response sheet.

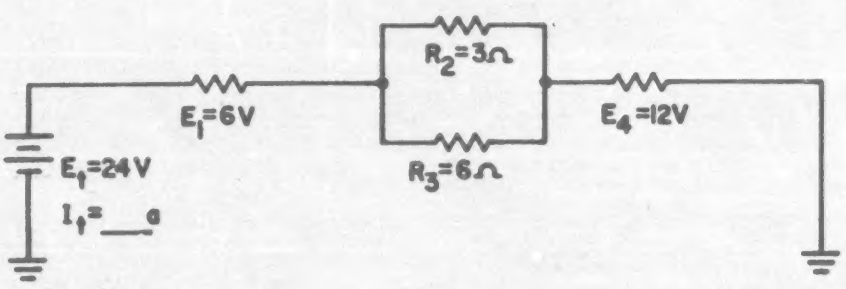
1.



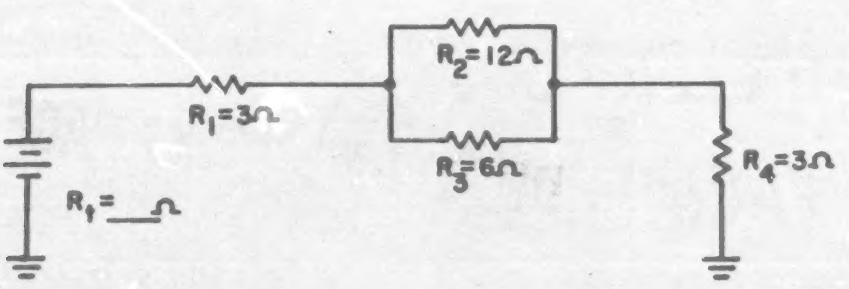
2.



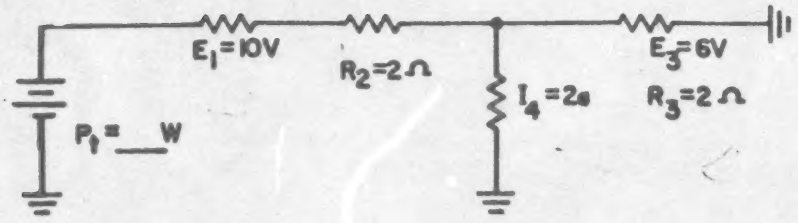
3.



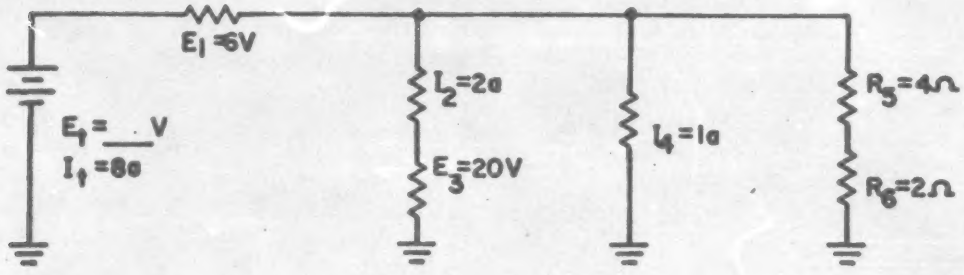
4.



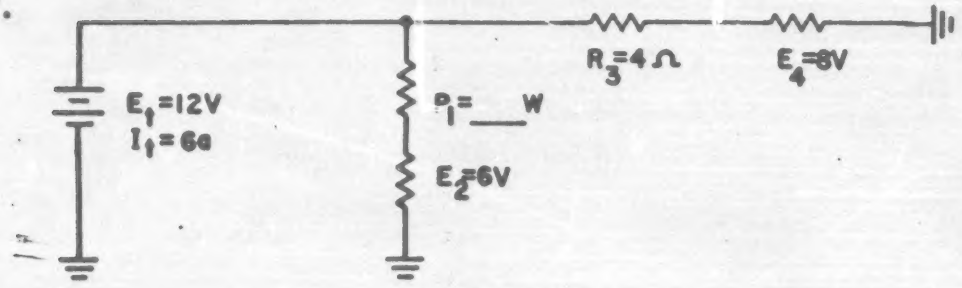
5.



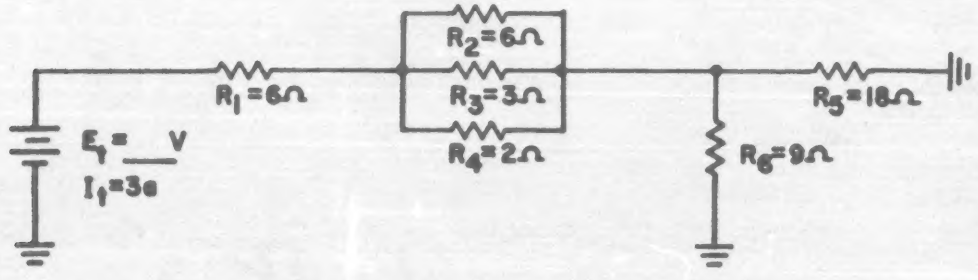
6.



7.



8.



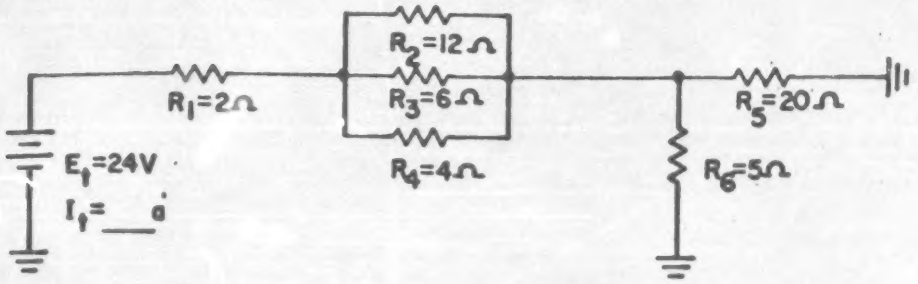
Have the instructor check your answers and circle the next frame number on the response sheet which you are to do.

Instructor's Initials _____

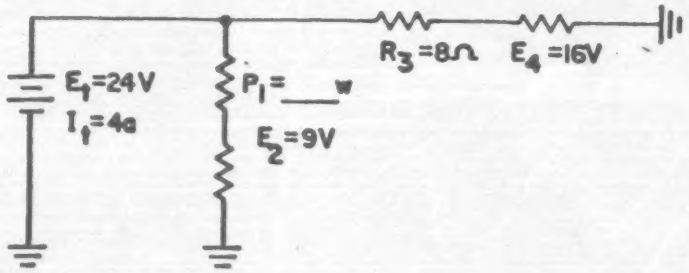
Note: If you need additional practice, you will be assigned the problems in Frame 37. If you don't need additional practice, the instructor will tell you to go to Frame 38.

Before starting this frame, reread frame 11. Frame 11 outlines the procedures for solving for unknowns in series-parallel circuits. Solve each of the following problems for the indicated unknown. Put your answers on the appropriate blanks on the response sheet.

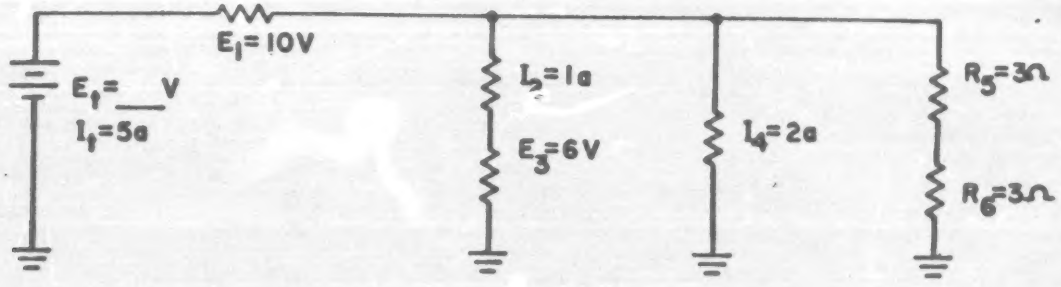
1.



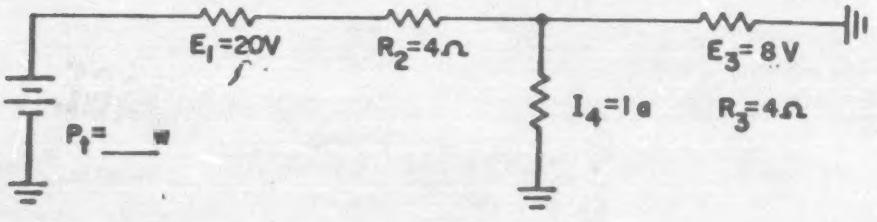
2.



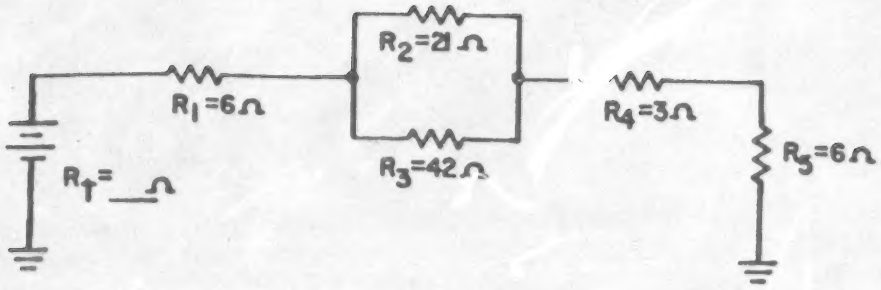
3.



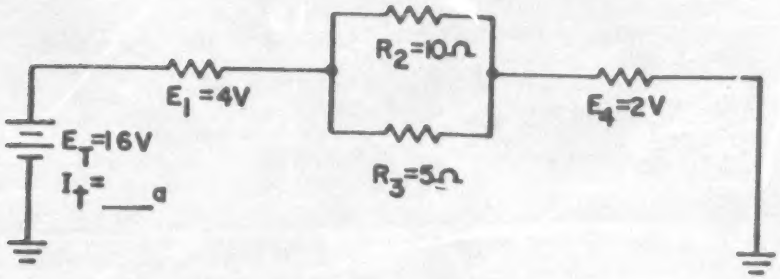
4.



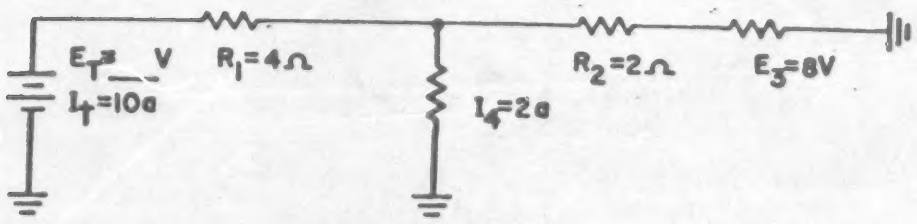
5.



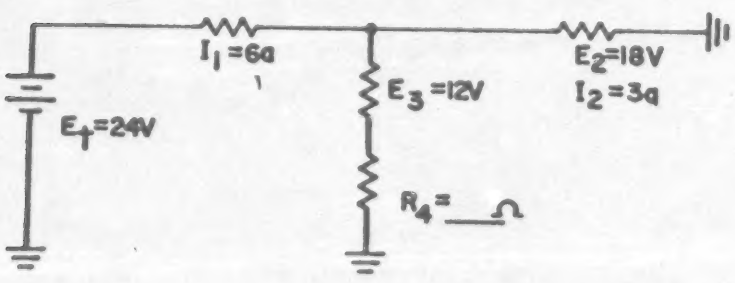
6.



7.



8.

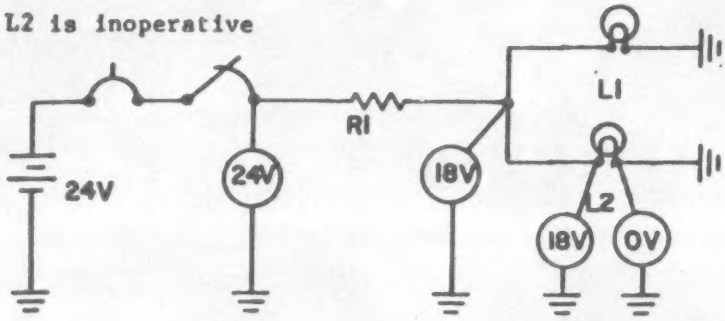


Have the instructor check your answers on the response sheet.

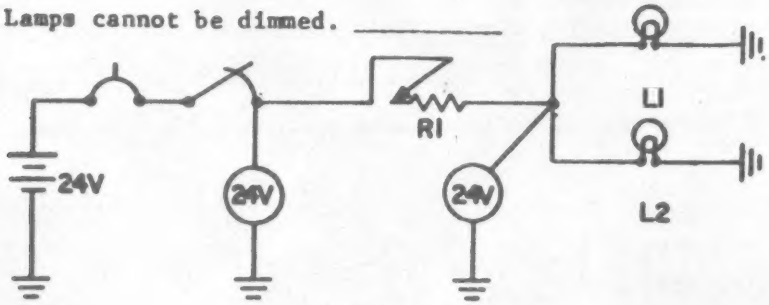
Instructor's Initials _____

Analyze the meter readings and/or circuit indications in each of the following circuits. Using the blank on the response sheet provided for each circuit, list the type of trouble and the faulty component.

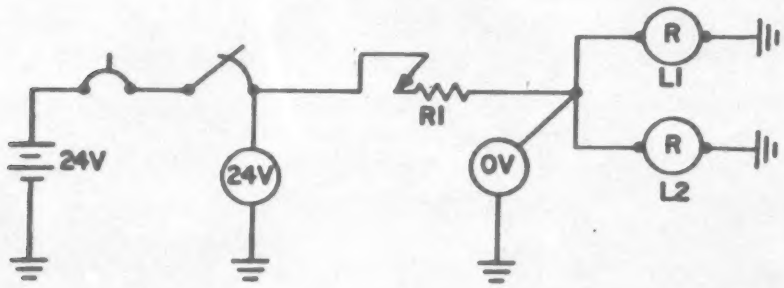
1. L2 is inoperative



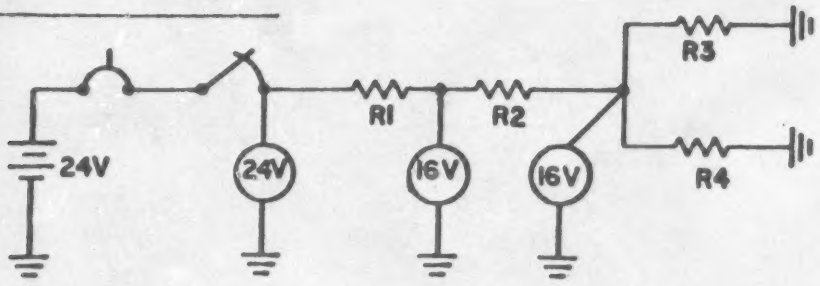
2. Lamps cannot be dimmed. _____



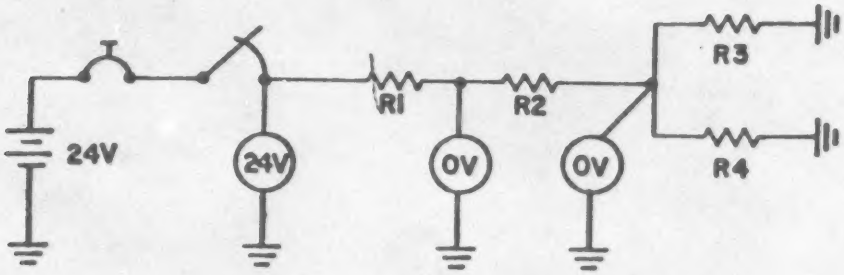
3. All lamps are inoperative. _____



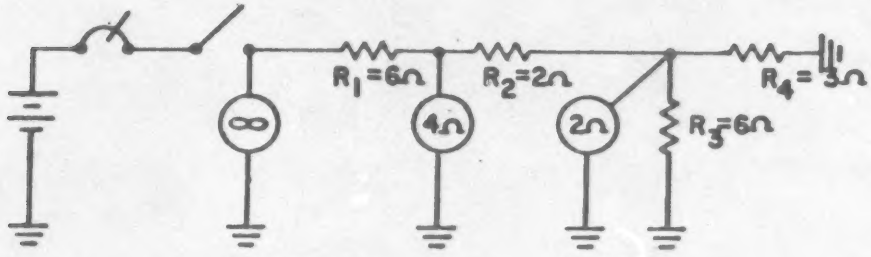
4. _____


24V
24V
R1
16V
R2
16V
R3
R4

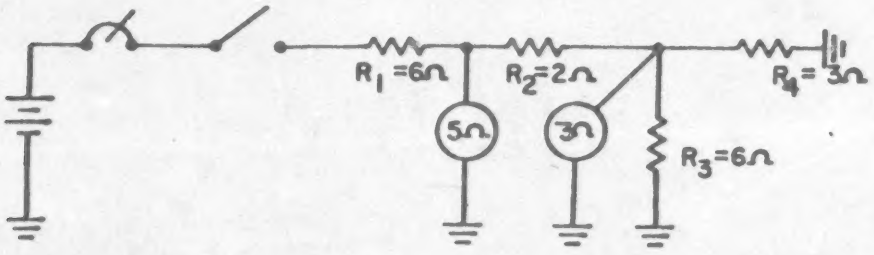
5. _____


24V
24V
R1
0V
R2
0V
R3
R4

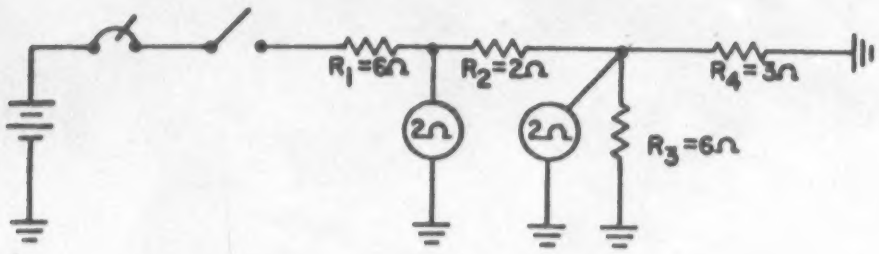
6. _____


∞
R1=6Ω
4Ω
R2=2Ω
2Ω
R3=6Ω
R4=3Ω

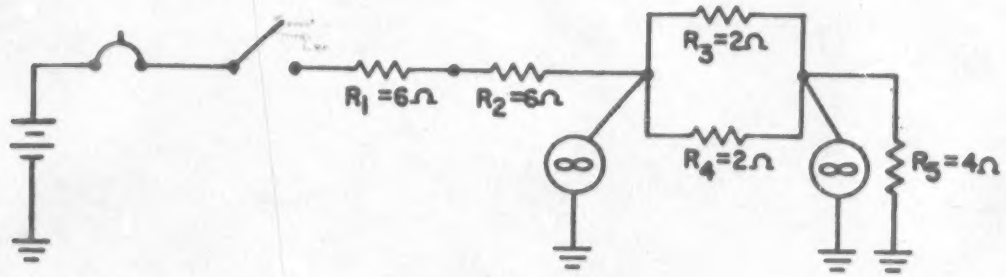
7. _____


R1=6Ω
5Ω
R2=2Ω
3Ω
R3=6Ω
R4=3Ω

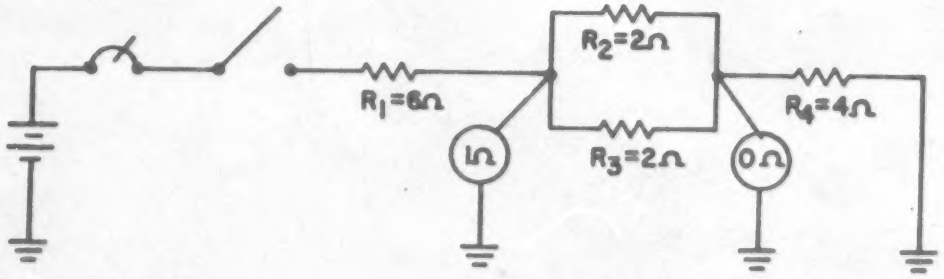
8. _____



9. _____



10. _____



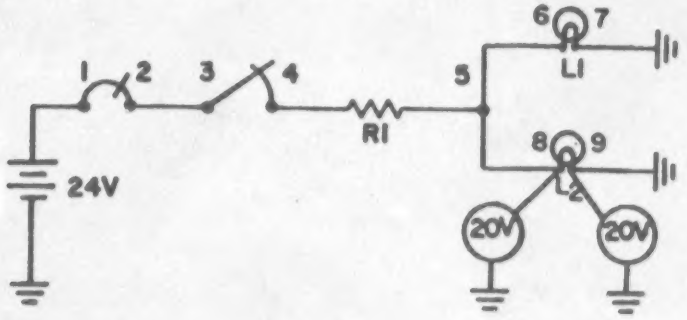
Have the instructor check your answers on the response sheet.

Instructor's Initials _____

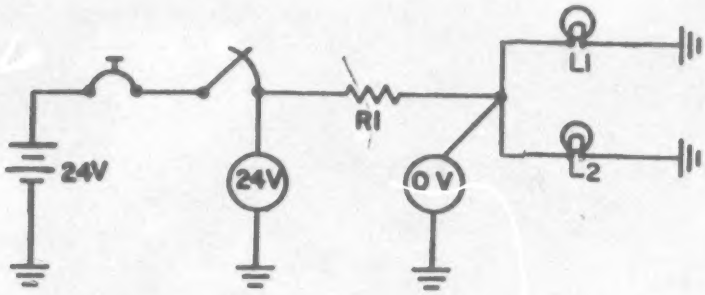
Note: If you need additional practice you will be assigned the problems in Frame 39. If you don't need additional practice you will see your instructor and ask to be given the appraisal for this text.

Analyze the meter readings and/or circuit indications in each of the following circuits. Using the blank on the response sheet provided for each circuit list the type of trouble and the faulty component.

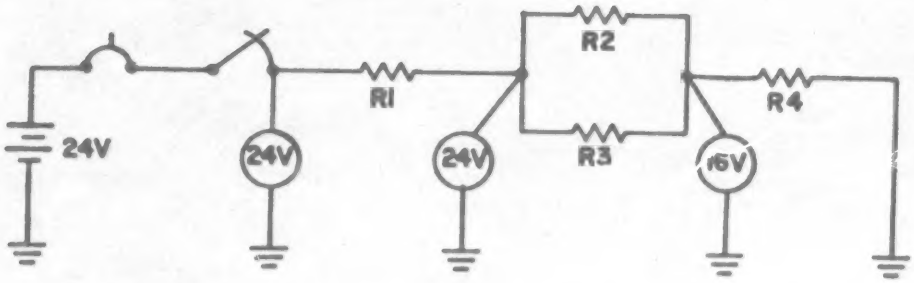
1. L_2 is inoperative. _____



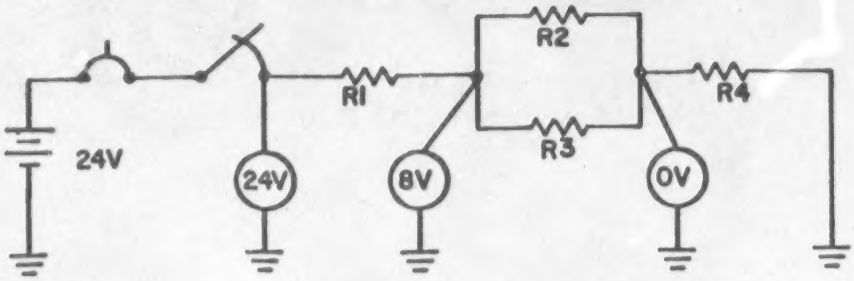
2. Both lamps inoperative. _____



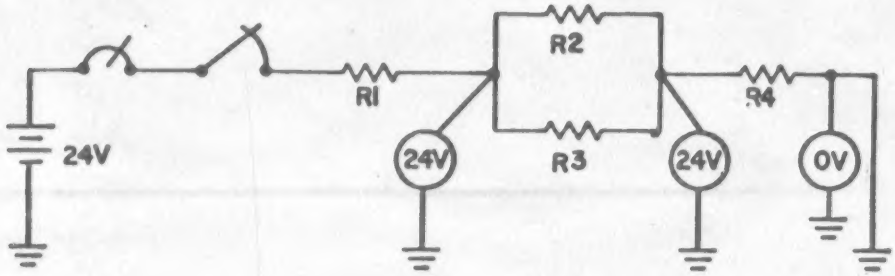
3. _____



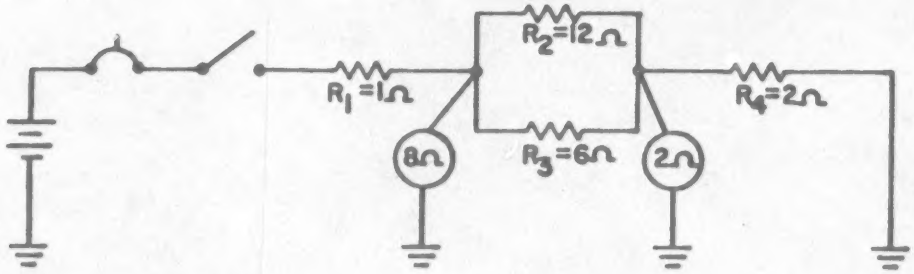
4. _____


24V
24V
R1
R2
R3
R4
8V
0V

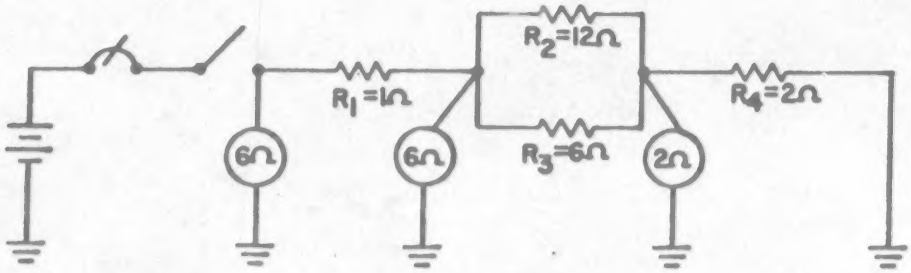
5. _____


24V
R1
R2
R3
R4
24V
24V
0V

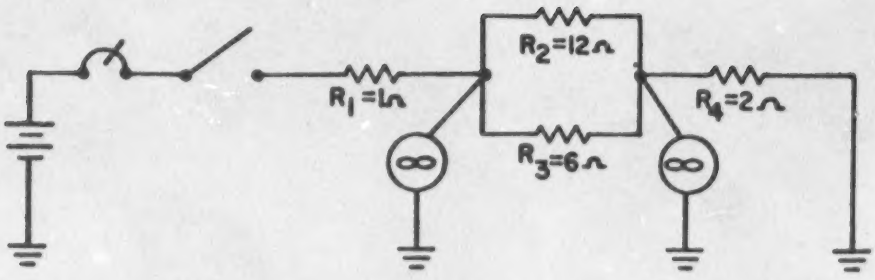
6. _____


R1=1Ω
R2=12Ω
R3=6Ω
R4=2Ω
8Ω
2Ω

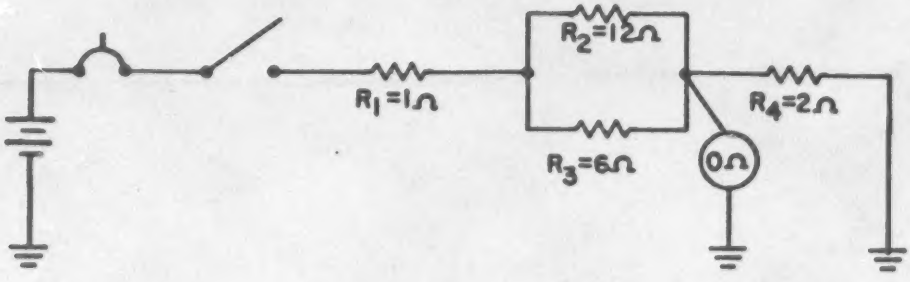
7. _____


R1=1Ω
R2=12Ω
R3=6Ω
R4=2Ω
6Ω
6Ω
2Ω

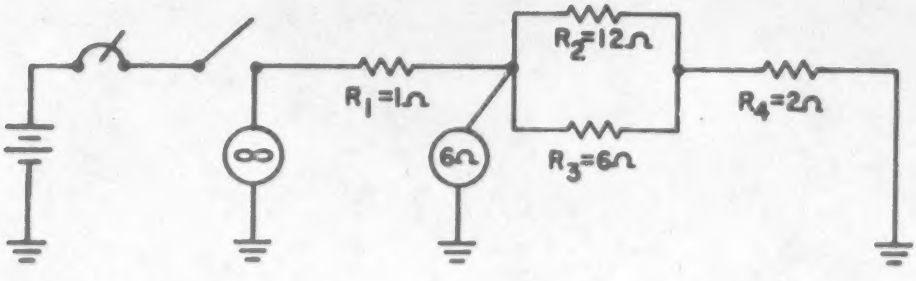
8. _____



9. _____



10. _____



Have the instructor check your answers to this frame on the response sheet.

Instructor's Initials _____

When you finish this frame see your instructor and ask to be given the appraisal for this text.

78-47252

WORKBOOK
3ABR42331-WB-119

Technical Training

Aircraft Environmental Systems Mechanic

SERIES-PARALLEL CIRCUIT PERFORMANCE

7 August 1979

CHANUTE TECHNICAL TRAINING CENTER (ATC)
3370 Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE
DO NOT USE ON THE JOB

764

Environmental Pneudraulics Branch
Chanute AFB, Illinois

3ABR42331-WB-119

SERIES-PARALLEL CIRCUIT PERFORMANCE

OBJECTIVE

Using a DC fundamentals trainer, construct a series-parallel circuit and measure electrical values with one instructor assist allowed for each task area.

EQUIPMENT

	Basis of Issue
Trainer P/N 521685, DC Fundamentals	1/student
Multimeter	1/student

SAFETY

Caution: Remove watches, rings, bracelets, etc., before starting any work on the equipment. It is also a good safety practice to work on the equipment with one hand. This practice reduces the chances of receiving an electrical shock to some vital body organ when working with electricity. Also remember that light bulbs, resistors, etc., do get HOT and could burn the skin.

PROCEDURE

Pay close attention to all directions that you are given in the workbook. When performing in the workbook, such as answering questions or recording electrical measurements, if your response is incorrect, restudy the information with instructor assistance if needed. Do not hesitate to ask the instructor questions. You will find that many of the exercises have the correct answers on page 6. After you have completed all the exercises, you will satisfactorily complete the progress check assigned by the instructor. If you wish, pages 12 through 14 may be removed for your convenience.

Before you leave your trainer for scheduled or unscheduled breaks, make sure the following items are done.

1. Make sure the SPST switch is turned OFF in the circuit.

2. Make sure the 28V DC bus bar has all the electrical leads removed from it.

3. Make sure the negative (black) bus bar has all the electrical leads removed from it.

4. Make sure the multimeter is properly stored during this period.

   a. The controls on the meter must be properly set for storage.

Supersedes 3ABR42331-WB-119, 31 October 1978.
OPR: 3370 TCHTG
DISTRIBUTION: X
3370TCHTG/TTGU-P - 300; TTVSA - 1

b. Leave the test leads attached to the meter.

c. Wrap the meter leads around the instrument.

d. Place the meter on the locker shelf.

5. When you return from the break, take the same meter and go back to work.

Exercise 1

1. Trainer preparation for exercises 2 and 3.

a. The metal plate on the right side of the trainer may be raised for the workbook to lay on.

b. Sign out a multimeter, see the lab instructor if assistance is needed.

c. Make sure that the instructor has connected power to the trainer. You will do this by measuring the power, with the multimeter, at the positive (red) and negative (black) bus bar. The bus bars are located in the lower right and left corners of the trainer. If you don't read a voltage (24V DC ± 4V DC), see your instructor.

d. Make sure that fuse wire is across the fuse holders of each of the three (3) ammeters on the trainer. This will protect the ammeter internal circuit from over load. If the fuse wire is burnt in two or is missing, see your instructor for assistance.

e. Pull the circuit breaker out (open) and turn OFF (open) two single pole single throw (SPST) switches.

f. Make sure all leads in the drawer are in good condition with a plug at both ends. If you find any damaged leads, give them to the instructor.

g. Examine the electrical lead ends, and note how you may connect them together if one lead is too short. See your instructor for assistance if needed.

Exercise 2

2. Build a series-parallel circuit. This circuit will be made up of two loads (light bulbs) in parallel with each other, and in series with one load (10 ohm resistor).

a. Using the electrical leads from the drawer, construct the series-parallel circuit shown in figure 1. This consists of a C/B (circuit breaker), SPST switch, two light bulbs in parallel with each other, and in series with a 10 ohm resistor.

Note: If an electrical lead is too short, you may connect leads together to prevent stretching or breaking them.

b. Before applying power to your series-parallel circuit, be sure you have a common ground for the two light bulbs in parallel, which are wired in series with a 10 ohm resistor.

c. If you study this series-parallel circuit in figure 1, you will find that IF power is applied, electrons will flow from point 1, the negative (-) bus bar, to point 2, then from point 2 they will divide and some will flow through the (right) light bulb to point 3 and on to point 5. Looking back at point 2 you will also find the electrons have another path to flow. They will flow through the wire to point 4 and on through the (left) light bulb to point 5. After the electrons, which have been divided into two paths through the light bulb's parallel circuit, regroup at point 5, they will enter the series portion of this circuit. The electrons will leave point 5, moving on to point 6 on through the resistor to point 7, then on through the remaining circuit to the positive (+) bus bar IF power is applied.

Exercise 3

3. Measuring electrical values in the series-parallel circuit constructed on the trainer from figure 1.

a. Make sure the circuit from figure 1 is correctly constructed on the trainer and them turn ON the power (SPST switch and C/B). Measure and record the voltage readings with the multimeter as required in figure 1.

(1) You should note that points 1, 2, 4 are all equally negative in the circuit. This is why you can put the meters (-) negative Black lead at either point to measure voltage applied across each bulb.

(2) You should also note that the total voltage applied can be measured at points 1 and 12. You may also add the reading of points 6 & 7 to the applied voltage across one of the bulbs.

b. Measure and record the total current flow in the circuit constructed as shown in figure 2.

c. Measure and record the voltage drop across the 10 ohm resistor at points 6 (-) to 7 (+) in figure 2.

Note: Leave the ammeter connected in the circuit until instructed to remove it.

d. Observe the ammeter in the circuit and do the following:

(1) Using a short lead from the drawer, you will connect it across the resistor from points 6 & 7 as shown in figure 3. This will simulate the effect a shorted resistor will have on a circuit.

(a) Note the light brightened because resistance decreased and note the current (amp) increased.

e. Measure and record the total current flow in the circuit with the shorted resistor (simulated) in figure 3.

f. Leaving the circuit connected as shown in figure 3, measure and record the voltage reading at points 6 and 7 in figure 3.

g. Answer the questions in figure 3.

h. Observe the ammeter in the circuit and do the following:

(1) Remove the short lead from points 6 and 7, the one across the resistor shown in figure 3 used to simulate a shorted resistor.

(2) Using the same short lead you will now connect it across either light bulb (load) in the parallel circuit part of this series-parallel circuit. Either across points 2 and 3 or points 4 and 5. We show it across points 4 and 5 in figure 4. Note the ammeter reading increased and the lights both go out.

(a) If you trace from point 1 to 12, you will find only the resistor is left in the circuit and carrying current flow. The current will flow from point 1 to 2 to 4 to 5 and on through the resistor to point 12. It flows around the light bulbs because there is less opposition to current flow in the wires from points 2 through 5 then in the bulbs.

i. Measure and record the total current flow in the circuit with the shorted bulb (simulated) in figure 4.

j. Leaving the circuit connected as shown in figure 4, measure and record the voltage reading with the multimeter as required in figure 4.

k. Answer the questions in figure 4.

l. Remove all the leads and store them in the drawer and report to your instructor for a progress check assignment.

CORRECT RESPONSES FOR FIGURES 1 through 4.

Figure 1

CHECKPOINTS		VOLTAGE READINGS
2 - 3 or 1 - 3		8.5 ± .5V DC
4 - 5 or 1 - 5		8.5 ± .5V DC
6 - 7		16 ± 1.0V DC
1 - 12	Total	26 ± 3.0V DC

Figure 2

CHECKPOINTS		READINGS
1 - 2	Total current	1.6 ± .4 amps
6 - 7	Voltage drop	16 ± 1.0 volts

Figure 3

Total current flow 3.0 ± .3 amps

Voltage points 6 and 7 0 volts

1. a

2. b

CHECKPOINTS	READINGS
4 - 5	0 volts
1 - 2	2.2 ± .2 amps

1. a

PROGRESS CHECK INSTRUCTIONS

This progress check will require you to correctly construct a series-parallel circuit and measure electrical values with one instructor assist allowed for each task area. An instructor assist for each task area is defined as an aid, such as technical direction or explanation given to the student, who can proceed no further on his/her own. The instructor will initial your work after you satisfactorily completed each task of the progress check. If you do not pass the progress check, you will follow the instructions given by the instructor.

You <u>will not</u> communicate (talk, etc.) with other students during the progress check without your lab instructor's permission.

You <u>will not</u> use fellow student's work to solve the problems in this progress check.

You must satisfactorily complete this progress check before further progression to other lab progress checks.

Have your lab instructor select and initial on page 8 or 9 the series-parallel circuit progress check you are to draw on figure 5. Using a lead pencil only, draw in the series-parallel circuit leads between the various symbols. Later you will construct this circuit on the trainer. After you have satisfactorily completed the progress check, you will follow the instructions on page 11.

_____ Instructor's initials. Assigned progress check #1.

After completion of each task listed below, do not progress until the instructor has initialed your work for that task.

TASK 1 Draw the series-parallel circuit. This circuit will be made up of two loads (light bulb and 500 ohm resistor) in parallel with each other, and in series with one load (10 ohm resistor), SPST switch, and circuit breaker in figure 5.

_____ Instructor's initials. Task initials _____ _____

TASK 2 Construct the series-parallel circuit drawn in figure 5 on the trainer and demonstrate an operations check for the instructor.

_____ Instructor's initials. Task initials _____ _____

TASK 3 Measure and record the electrical values required below. Take these values from the circuit in figure 5 assigned.

Total current flow _____ amps.

Total voltage to the circuit _____.

Voltage drop across the bulb _____.

Voltage drop across the 500 ohm resistor _____.

Voltage drop across the 10 ohm resistor _____.

_____ Instructor's initials.

Turn to page 11 for further instructions.

Note: If the instructor provides an instructor assist for a task, the instructor will initial behind task initials (see objective).

_____ Instructor's initials. Assigned progress check #2.

After completion of each task listed below, do not progress until the instructor has initialed your work for that task.

TASK 1 Draw the series-parallel circuit. This circuit will be made up of two loads (light bulb and 10 ohm resistor) in parallel with each other, and in series with one load (10 ohm resistor), SPST switch, and circuit breaker in figure 5.

_____ Instructor's initials. Task initials _____ _____

TASK 2 Construct the series-parallel circuit drawn in figure 5 on the trainer and demonstrate an operations check for the instructor.

_____ Instructor's initials. Task initials _____ _____

TASK 3 Measure and record the electrical values required below. Take these values from the circuit in figure 5 assigned.

Total current flow _____ amps.

Total voltage to the circuit _____.

Voltage drop across the bulb _____.

Voltage drop across the 10 ohm resistor _____. In the parallel part of the circuit.

Voltage drop across the 10 ohms resistor _____. In the series part of the circuit.

_____ Instructor's initials.

Turn to page 11 for further instructions.

Note: If the instructor provides an instructor assist for a task, the instructor will initial behind task initials (see objectives).

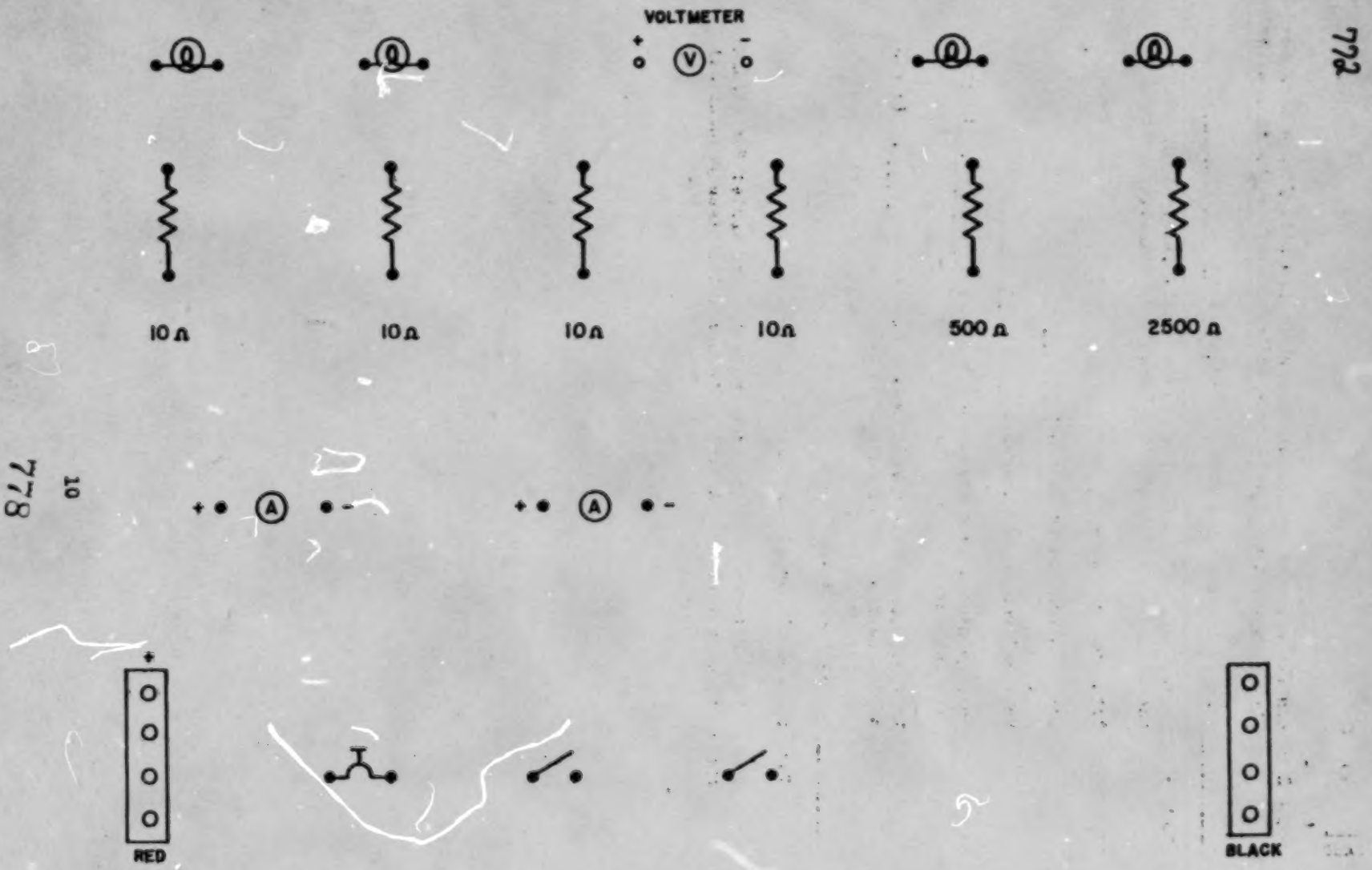


Figure 5.

After you have satisfactorily completed the progress check, you will do the following:

1. Put all the good leads in the drawer of the trainer.

2. Give all the broken leads to the lab instructor with the parts.

3. Place the work table in the down position on the trainer.

4. Return the multimeter to its storage cabinet. Be sure the controls on the meter are set correctly for storage.

5. You will turn in your work to the lab instructor before you leave the lab area.

Note: You may review any part or all of this workbook if you wish, but your work will not leave the lab area without the lab instructor's permission.

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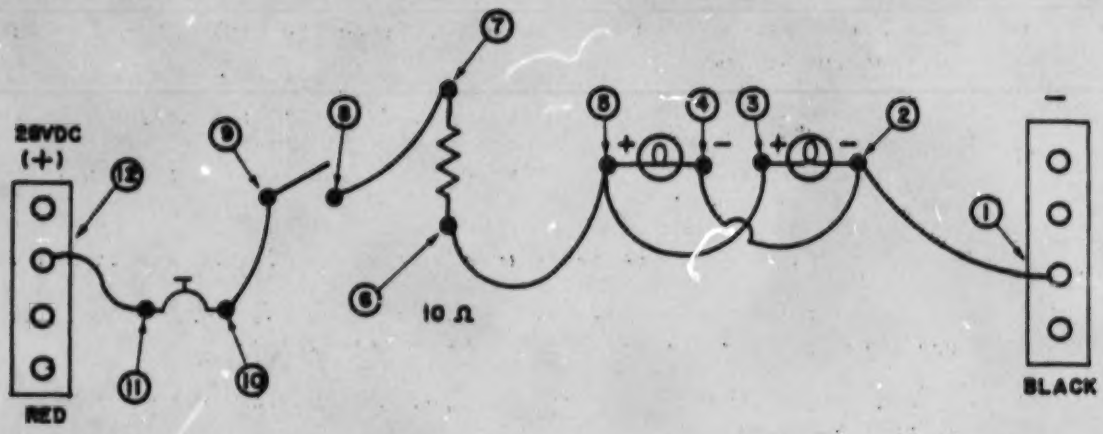

Figure 1.

CHECKPOINTS		VOLTAGE READINGS
2 - 3 or 1 - 3		_____ volts
4 - 5 or 1 - 5		_____ volts
6 - 7		_____ volts
1 - 12	Total	_____ volts

Correct answers are on page 6. Go to step "b" in exercise 3.

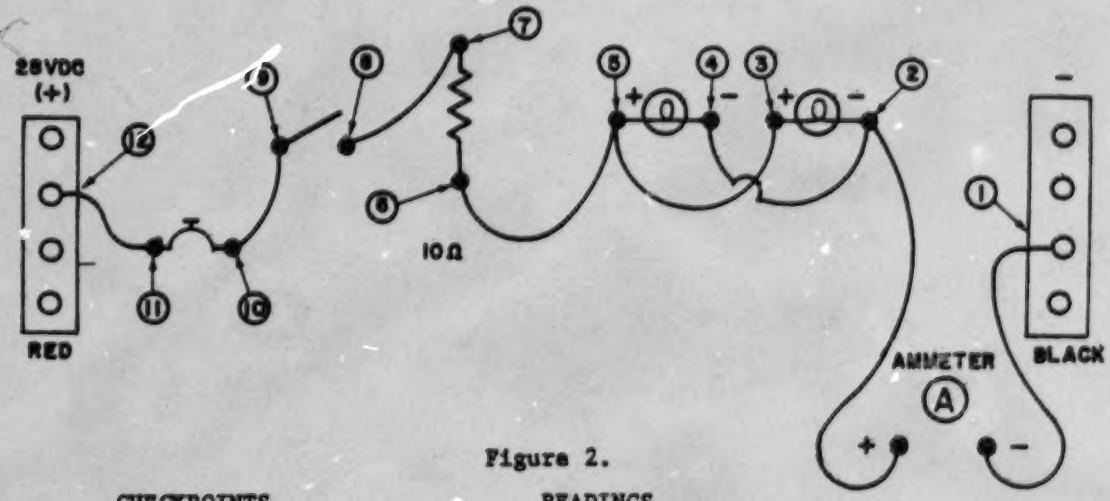

Figure 2.

CHECKPOINTS	READINGS
1 - 2	Total current _____ amps.
6 - 7	Voltage drop _____ volts.

Correct answers are on page 6.

Go to step "d" in exercise 3.

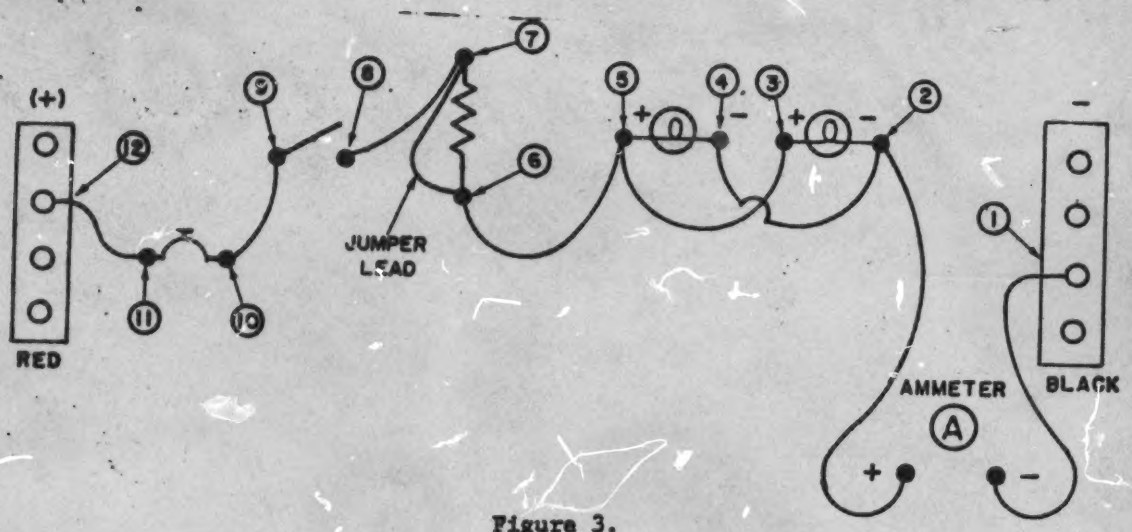

Figure 3.

Total current flow _____ amps.

Voltage points 6 and 7 _____ volts.

1. The current flow increased

   a. because the total resistance in the series-parallel circuit decreased due to the simulated short in the resistor.

   b. because the total resistance in the series-parallel circuit increased due to the simulated open in the resistor.

2. The voltage drop across points 6 and 7

   a. increased.

   b. decreased.

Correct answers are on page 6.

Go to step "h" in exercise 3.

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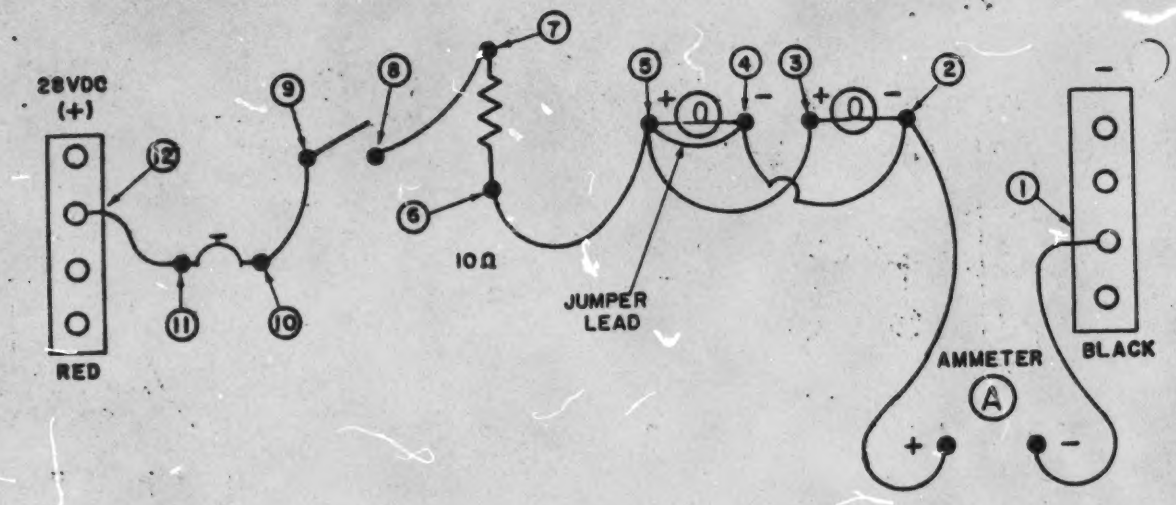

Figure 4.

CHECKPOINTS	READINGS
4 - 5	_____ volts
1 - 2	_____ amps

1. The current flow increased

   a. because the short caused the total resistance to decrease, allowing the current flow to bypass the parallel loads (bulbs) causing the lights to go out. Current flow is from point 1 to 2, not through the right light bulb, but around it over to point 4. From point 4 it goes around the left bulb through the jumper lead to point 5 and on through the resistor over to the positive bus bar.

   b. because the short caused the total resistance to decrease, allowing the lights to go out and all of the current to flow through both light bulbs and not the resistor and on to the positive bus bar.

Correct answers are on page 6.

Go to step "1" in exercise 3.

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Technical Training

MECHANIC

Aircraft Environmental Systems Mechanic

INTRODUCTION TO RELAYS

9 December 1970

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR42231-PT-115C, 11 July 1969.
OPR: TSDS
DISTRIBUTION: X
TSDS - 500; TSOC - 2

Designed For ATC Course Use

FOREWORD

This programmed text was prepared for use in Course 3ABR42231, Aircraft Environmental Systems Repairman. The materials contained herein have been validated with 36 students from the subject course. At least 90% of the students achieved the objectives as stated. The average time required to complete the text is 58 minutes.

OBJECTIVES

Upon completion of this programmed text, you will be able to:

1. Accurately identify relay symbols.

2. Correctly select from various circuits a minimum of two that are relay control circuits.

3. Correctly select from several circuits a minimum of two that are relay controlled circuits.

4. Label the parts of a relay with 70% accuracy.

INSTRUCTIONS

This program presents information in small steps called frames. After reading each frame, slide a mask (sheet of paper or cardboard) down the page until you see a short row of slashes (/////). Read the question; answer it and then slide the mask down until the correct answer is exposed. If you miss a correct answer, or you are not sure, restudy the appropriate frame.

Frame 1

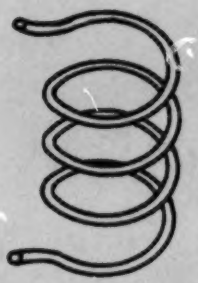
While aircraft and missiles are not really human, they are capable of doing some things that seem almost human. They can respond to orders just as we do. Through the use of small electrical devices called "relays," they can transmit electrical orders to mechanical motors to operate vital parts of the aerospace vehicle.

////////////////

No response required

Frame 2

To better understand a relay, we will examine the "working parts." Below is a coil of wire that will be used as an electromagnet. Perhaps you recall that as current flows through the coil a magnetic field is built up around the coil. Like any magnet, it will attract any nearby metallic object that a magnet normally attracts.

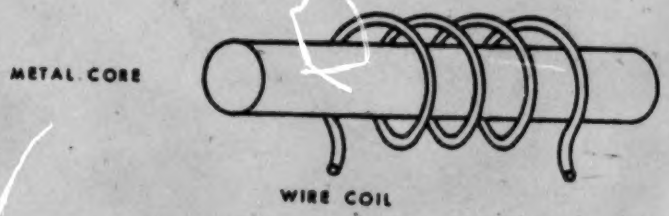


////////////////

No response required

Frame 3

A soft iron core is put into the center of the coil. While this bar does not actually touch the coil of wire or have electrons flowing through it, it does make the magnetic field stronger by providing an easier path for the magnetic flux to travel.



So far we have seen that a relay may be made up of a coil of_____ and a soft iron_____.

////////////////

wire core

1

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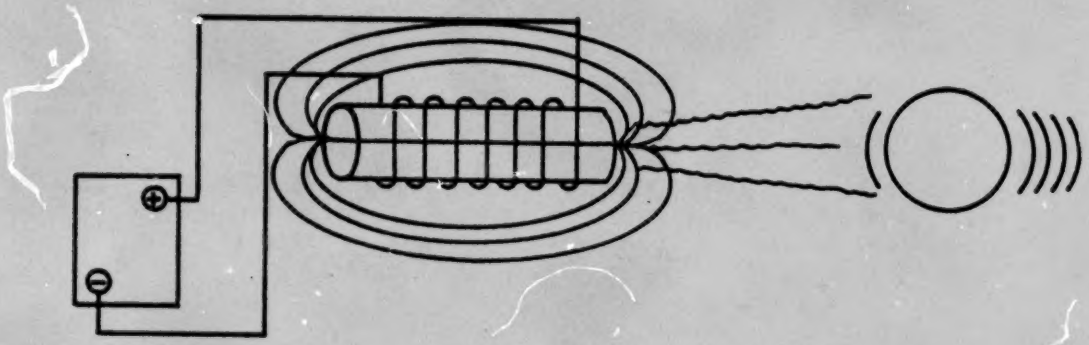
Frame 4

If the wire coil is connected to a battery, a magnetic field will build up around the coil. The field will reach out to attract any object that is normally attracted by magnets.



////////////////////

No Response Required

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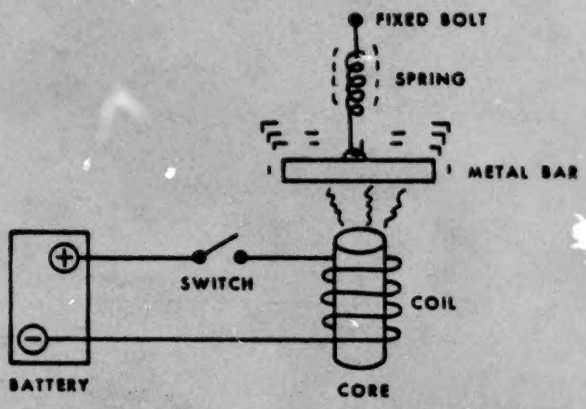
Because our electromagnet has the ability to attract certain metallic objects, we can make it do some useful work.



Study the illustration carefully and then complete the statements below by underlining the correct word(s).

a. The CORE is actually a (soft-iron) (hard steel) bar.

b. A (battery) (switch) supplies current to the electromagnet.

c. Current flows through the (coil) (core).

d. A magnetic field flows through the (coil) (core).

e. The current is CONTROLLED by the (battery) (switch).

f. If the switch is turned on, the magnetic field will (attract) (repel) the metal bar.

g. The spring will pull the metal bar back to its original position if the switch is turned (on) (off).

////////////////

a. soft iron. b. battery. c. coil. d. core.

e. switch. f. attract. g. off.

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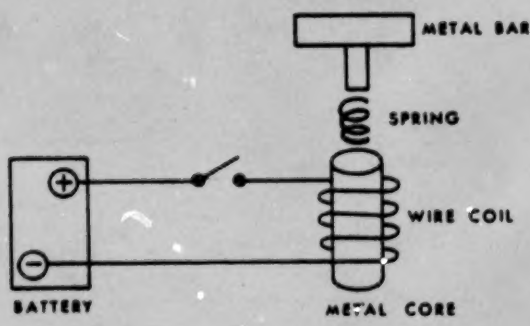
Frame 6

Study this illustration carefully and complete the statements that follow by underlining the correct word(s).



a. If the switch is closed, the metal bar will (compress) (stretch) the spring.

b. The battery supplies current to the (coil) (core).

c. The switch controls current through the (coil) (core).

d. The movable parts are the (coil) (coil and spring) (metal bar, coil and spring) (spring and metal bar).

e. The strength of the magnetic field is determined by the (spring) (current).

f. There (is) (is no) current flowing in the coil with the switch open.

g. There (is) (is no) current flowing in the upper metal bar.

h. The only purpose of the spring is to (pull the metal bar down) (push the metal bar away from the core).

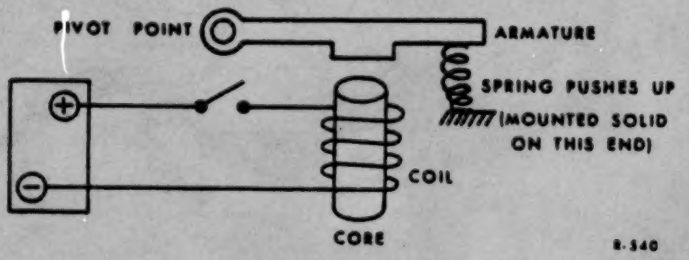
////////////////

a. compress. b. coil. c. coil d. spring and metal bar.

e. current. f. is no. g. is no.

h. push the metal bar away from the core.

Here is another way our electromagnet can be setup to pull on a metal bar (armature). Notice that the bar is pivoted (hinged) on one end. It can be pushed up by the spring and pulled down by the electromagnet. The proper name for this metal bar is the ARMATURE. Complete the statements below by underlining the correct word.



a. The battery sends current into the pivoted armature. (true) (false)

b. If the armature is hinged at the pivot point, the (right) (left) end of the armature will move down.

c. The spring will return the armature to its normal position anytime the switch is (open) (closed).

////////////////////

a. false. b. right.

c. open (if it is closed the magnetic field will pull the armature down).

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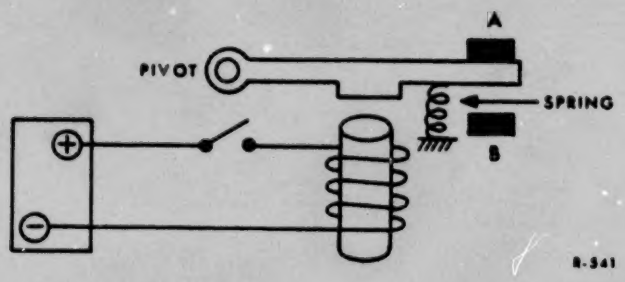
Frame 8

In this illustration we have added something new. There are two contacts labeled "A" and "B." Underline the correct answer after you have carefully studied this illustration.



a. If the switch is open, the armature will be resting against contact (A) (B).

b. If the switch is closed, the armature will be drawn against contact (A) (B).

c. When the coil is turned OFF, the armature will normally rest against contact (A) (B).

d. Current from the battery will flow through the armature. (true) (false).

////////////////

a. A. b. B c. A

d. False (Current flows only through the coil).

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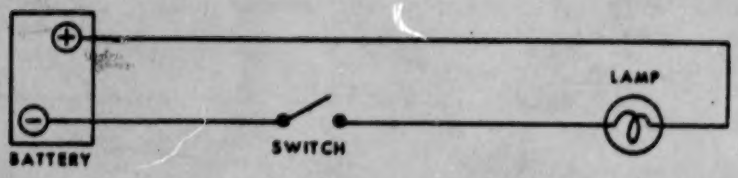
For a moment, let's take a look at a simple circuit.



All we need to do is close the switch and the lamp will light. The battery supplies current to light the lamp when the switch is closed. The switch completes the path from the battery's negative terminal through the lamp, and back to the positive terminal.

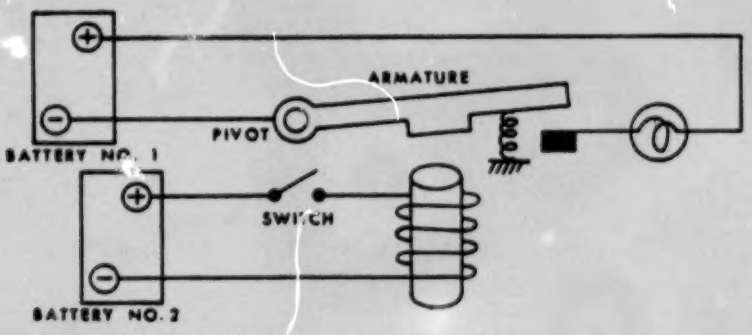
////////////////

No Response Required

786
Frame 10

Now we can put our electromagnet to work. Remember we normally turn a switch on and off with our fingers. What is to keep us from using our electromagnet to open and close the circuit between the battery and the lamp?

Look at this illustration and then underline the correct word in the statements below.



a. The switch controls current through the (coil) (lamp).

b. Current for the electromagnet's coil is supplied by battery (No. 1) (No. 2).

c. Current for the lamp is supplied by battery (No. 1) (No. 2).

d. Current will flow from battery No. 2 to the lamp. (true) (false)

e. The current that lights the lamp flows through the (coil) (core) (armature).

f. After the switch is OPENED, the lamp will go out because the spring pushes the armature away from the contact. (true) (false)

g. Current flows through the pivot, armature, and contact to get to the lamp. (true) (false)

//////////////

a. coil b. No. 2 c. No. 1 d. false

e. armature f. true g. true

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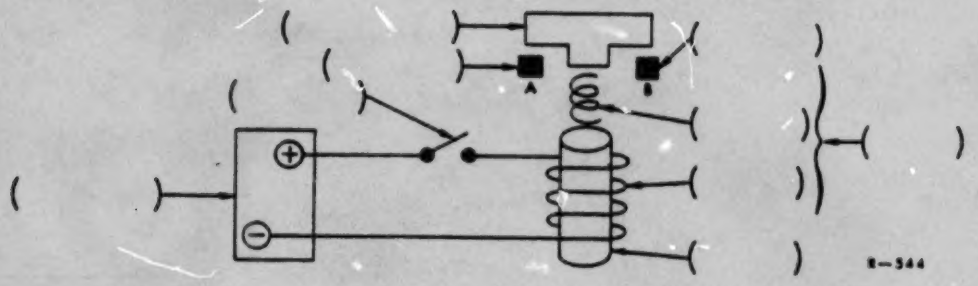
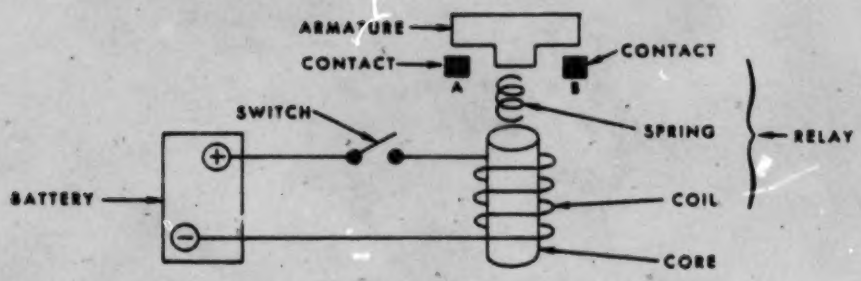
It's time to give our electromagnet and armature combination a name. From here on it will be referred to as a RELAY.

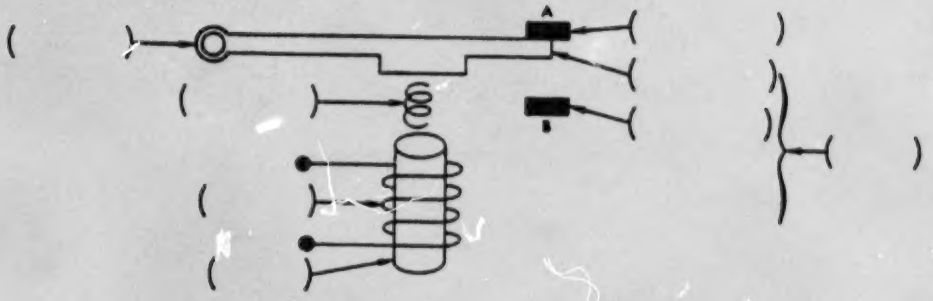
Label the parts in this illustration by writing the appropriate words in the spaces provided.



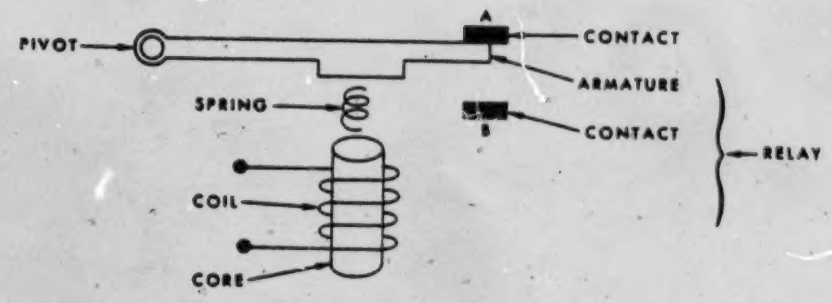


Frame 12

This is also an illustration of a relay. Label the parts by writing the appropriate word in the space provided.

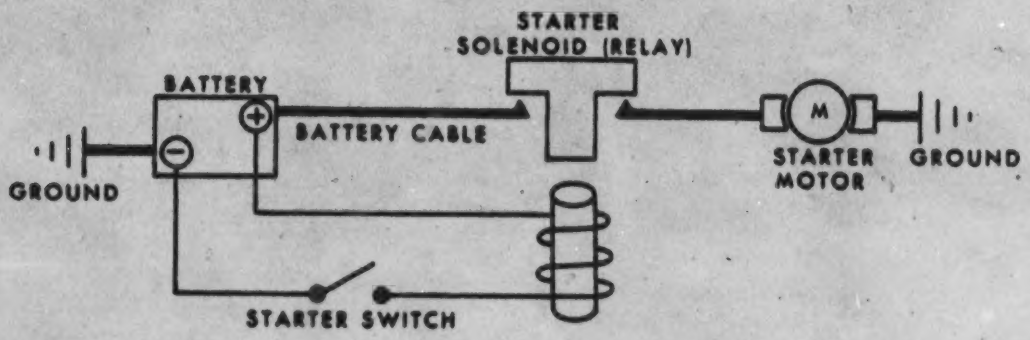


////////////////



Frame 13

Relays are actually remotely controlled switches. An example of their use is the starter solenoid (relay) in your car. It takes a LOT of current to start a cold engine. If the battery cables are too long, they will reduce the amount of current the battery can deliver to the starter motor. The trick then is to keep the battery cables short and, yet not have to get out of the car and go beneath the hood just to close a switch between the battery and the starter motor. This is an illustration of one way in which it is done.



Close the starter switch and the magnetic field pulls the armature of the relay down. Now current can flow from the battery, through the starter motor and armature of the relay, then back to the battery. In this case, it is easy to see how a very small wire can come up to the starter switch inside the car. All the starter switch has to do is complete the circuit from the battery's negative terminal, through the relay coil and back to the battery's positive terminal (or to the chassis). No current goes from the relay coil to the relay armature. It is the magnetic field that pulls the armature down and closes the contacts.

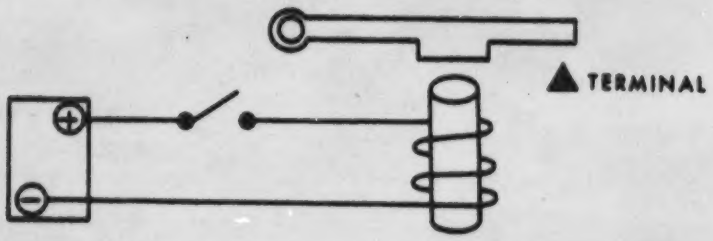
////////////////

No Response Required

By now you have noticed that we have two electrical circuits in our relay diagrams. One of these is the CIRCUIT THAT CONTROLS THE RELAY causing it to turn on and off. The parts that make up the circuit that controls the relay are the -

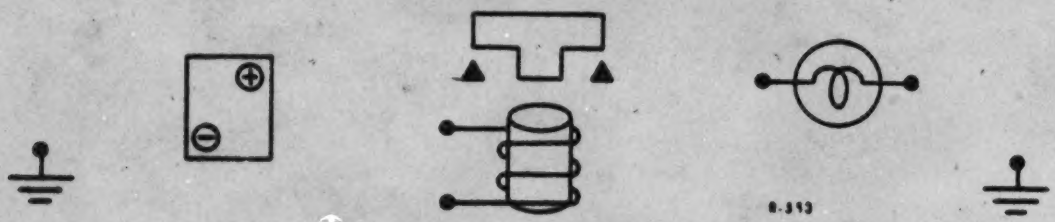
Below are some circuit components. Draw a line between them to show how YOU would wire them to make a circuit that CONTROLS just the relay.

Your answer should resemble this drawing.



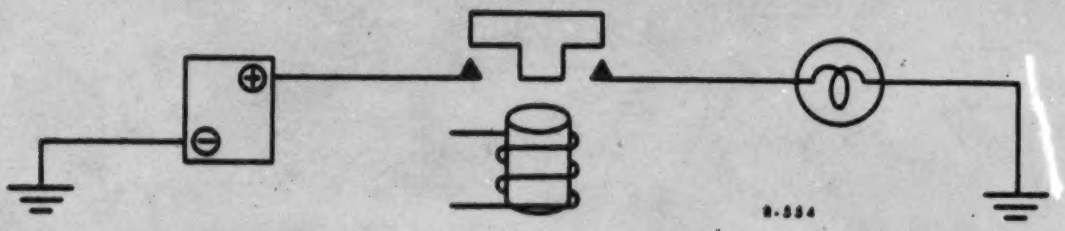
The second circuit we have illustrated is the CIRCUIT THAT IS CONTROLLED BY THE RELAY. It is usually made up of:

Draw a line between the components below to show how you would wire a CIRCUIT THAT IS CONTROLLED BY A RELAY.



//////////////////

Since we provided the "grounds," your answer should resemble this.



Notice the relay coil is NOT wired because it is part of the circuit that CONTROLS THE RELAY.

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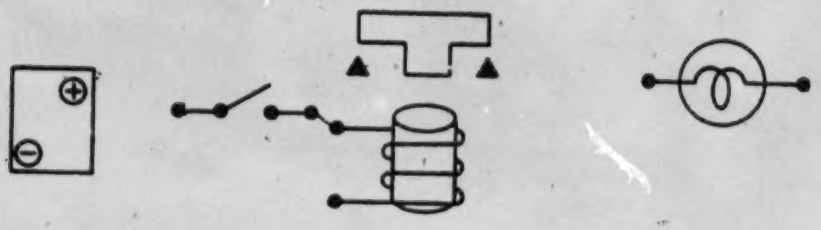
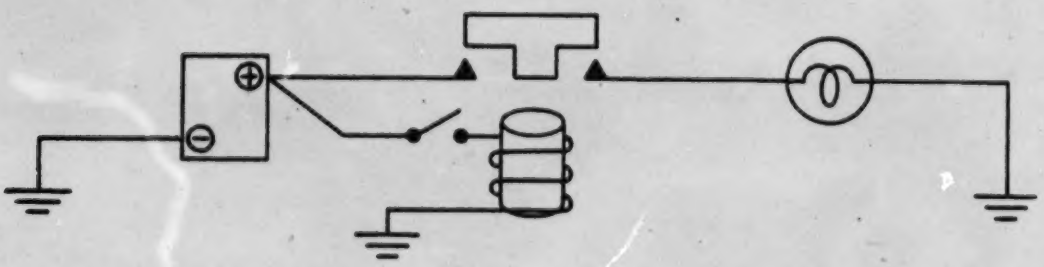
Frame 16

With the experience you have just gained in wiring a circuit that controls a relay and a circuit that is controlled by a relay, draw in the necessary wires to show how YOU would wire both a circuit that controls the relay, and the circuit that is controlled by the relay. YOU MAY USE ONLY ONE BATTERY.



////////////////////

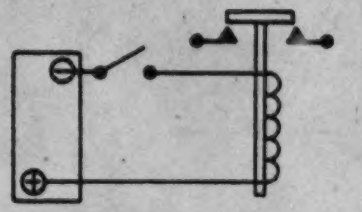
Your wiring should be similar to this - (if it is not, have your instructor explain what must be done to correct it).



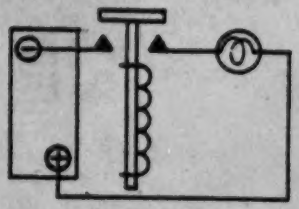
798

Frame 17

Below are several illustrations of electrical circuits. Look at them carefully and, when you are certain which kind they are, label them "Relay Control" for those circuits that simply turn the relay on and off, and "Controlled by a relay" for those circuits that are controlled by a relay. Write the correct answer in the space provided next to each illustration.

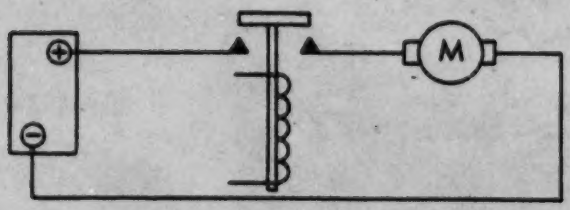


1. _____

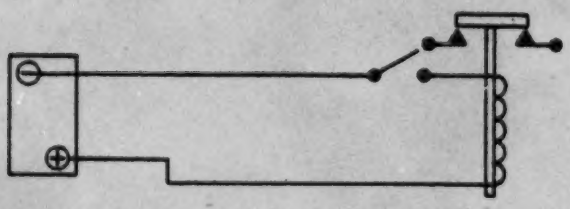


2. _____

R-557



3. _____



4. _____

R-558

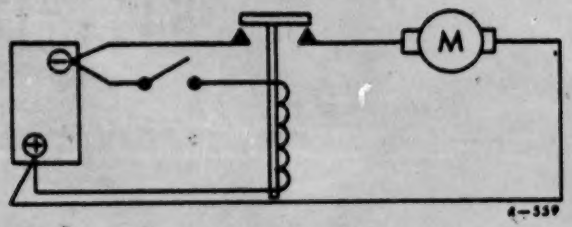
////////////////

1. relay control
2. controlled by a relay
3. controlled by a relay
4. relay control

15

794
Frame 18

You have learned that the circuits can be divided into two entirely different circuits. Study the circuit illustration below and underline the correct answer to the questions that follow.



a. The battery supplies energy for both circuits. (true) (false)

b. The switch is part of the circuit that is controlled by the relay. (true) (false)

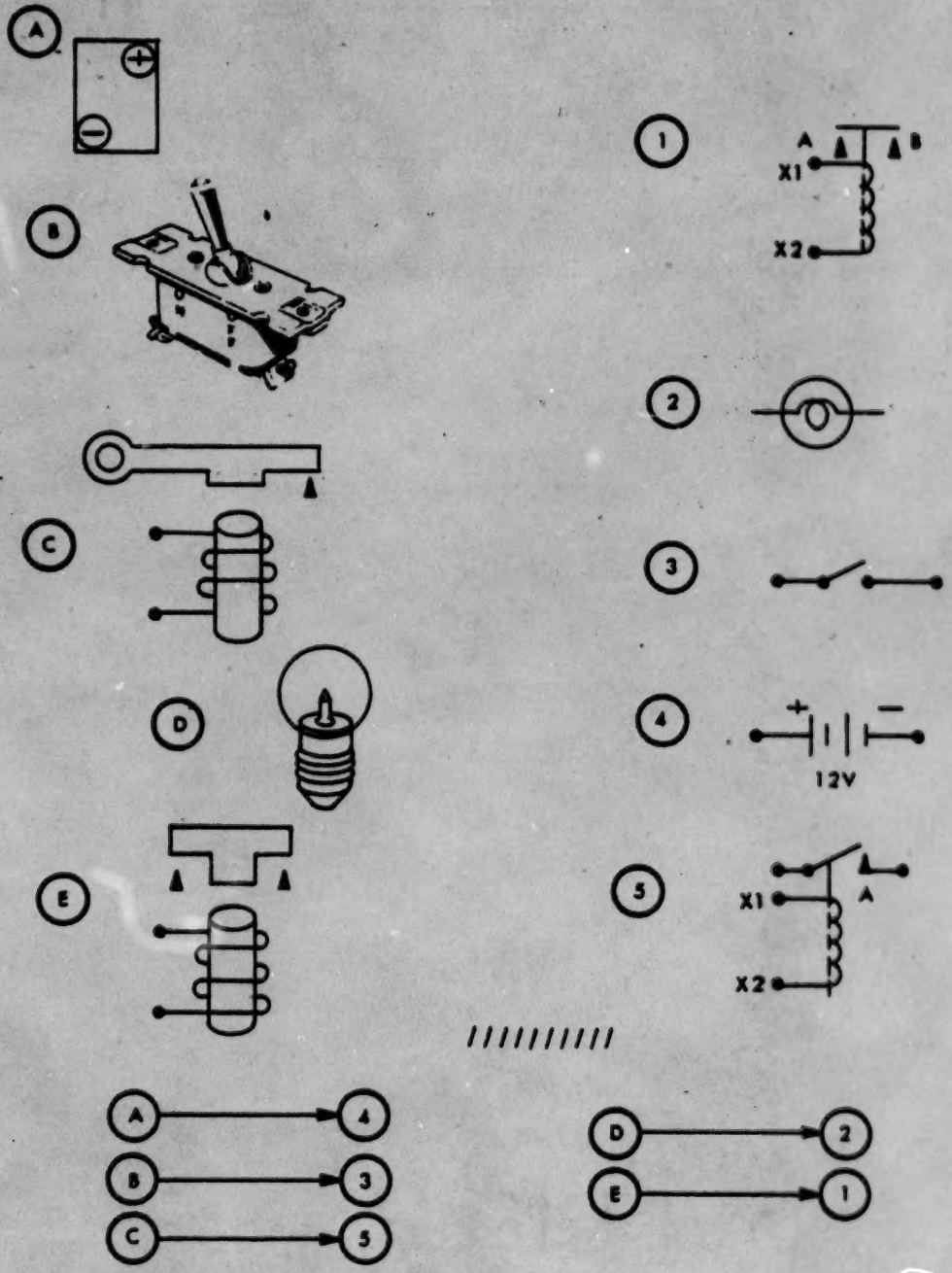
c. The motor is part of the circuit that controls the relay. (true) (false)

d. The relay coil is part of the circuit that controls the relay. (true) (false)

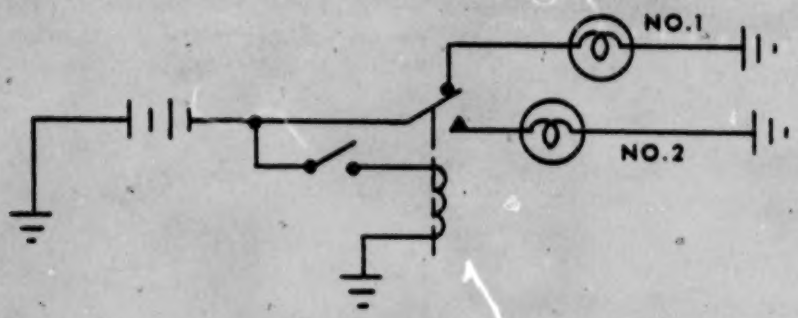
////////////////

a. true b. false c. false d. true

Symbols are used to represent the parts we have been working with so let's get acquainted with them. It saves a lot of time if you recognize the symbol and don't have to draw a picture of the battery, relay, etc. In the right column are the symbols for the units in the left column. Match them by drawing a line from the symbol to the device it represents.



A relay can be used to control more than one circuit. Study this circuit for a few minutes then underline the correct answer to the statements below.



a. With the switch in the position shown, (No. 1) (No. 2) (neither) lamp is lit.

b. If the switch is closed, (No. 1) (No. 2) (neither) lamp will light.

c. The switch lets current flow to both lamps if it is closed. (true) (false)

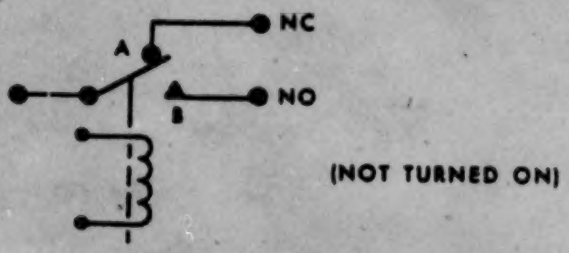
d. The switch controls current ONLY through the relay coil. (true) (false)

e. Which circuit is NORMALLY closed when the relay is not turned on? (No. 1) (No. 2)

////////////////

a. No. 1 b. No. 2 c. False d. True e. No. 1

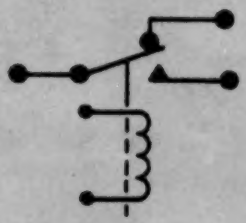
You saw in frame 20 that the relay is at a certain position when it is NOT turned on.

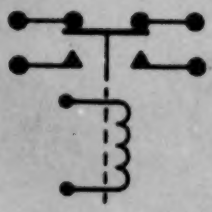


- so we labeled its upper contact (A) as NC - Normally Closed.

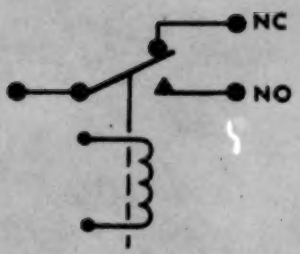
Contact B has been labeled as NO - Normally Open to show that circuit as being open when the relay is NOT turned on.

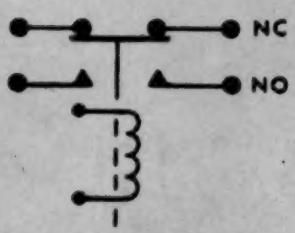
Label the contacts in the relay illustrations below to show their positions with the relay at rest (not turned on). You may abbreviate them NO and NC -





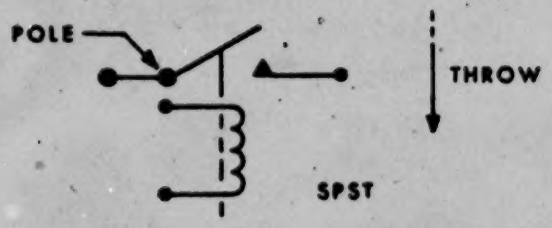
////////////////



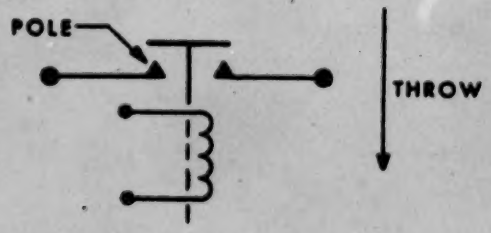


798
Frame 22

As with switches, relays are named according to their contact arrangements. This is called a "Single Pole, Single Throw" relay.



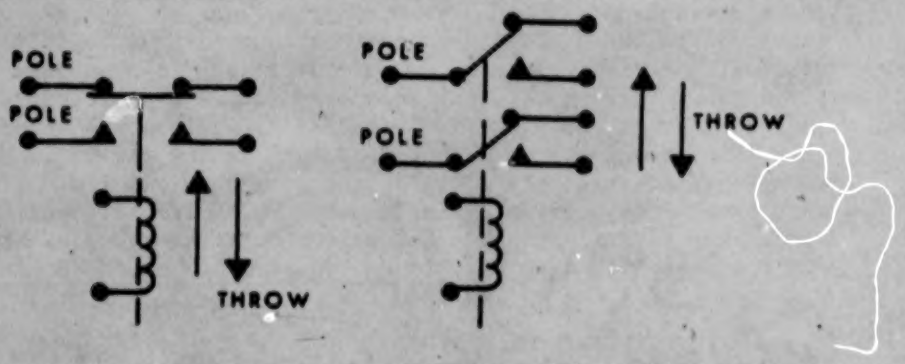
A "POLE" is the place where current enters the contacts and a "THROW" is the position the relay can be moved to in order to complete a circuit. The one shown above has a "Single Pole" and can be "thrown" (pulled down) to complete a path. Below is another SPST (single pole, single throw contact arrangement).



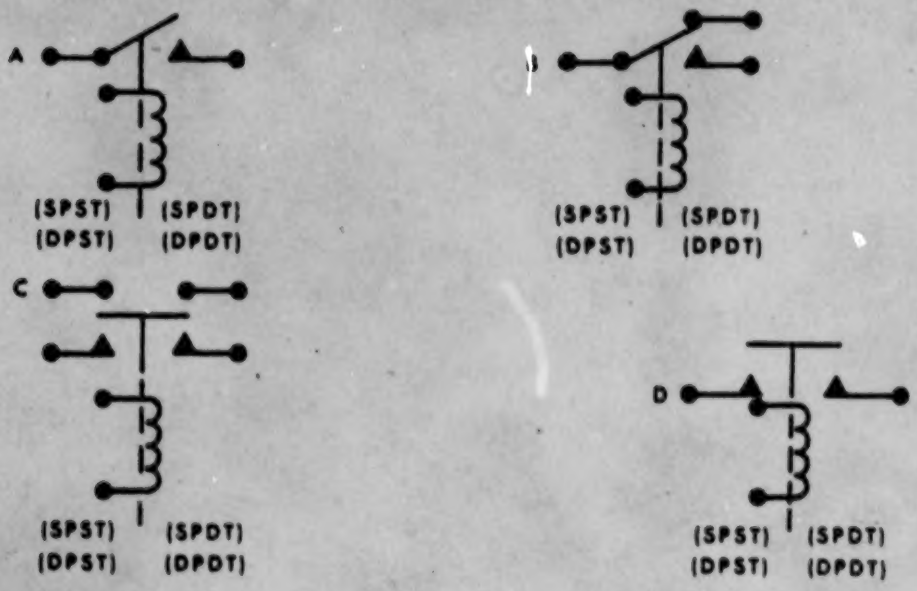
////////////////

No Response Required.

Study the illustration below and notice we have added a set of contacts.



In this illustration each relay has TWO poles (places for current to enter the contacts) and TWO throws (positions to which the relay can be thrown to complete the circuits). If the relay is turned off, the spring moves the contacts to their original (up) resting position and certain circuits are completed. If the relay is turned on, the contacts are thrown down to complete different circuits. So, this relay would correctly be called a DPDT or double-pole, double-throw. Select the correct abbreviation for the contact arrangements below by underlining the correct answer.



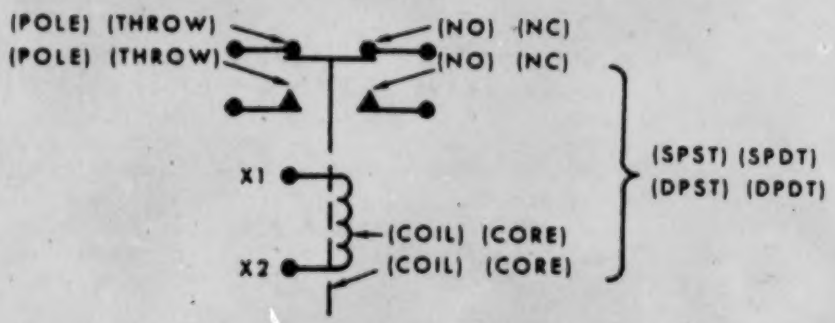
////////////////

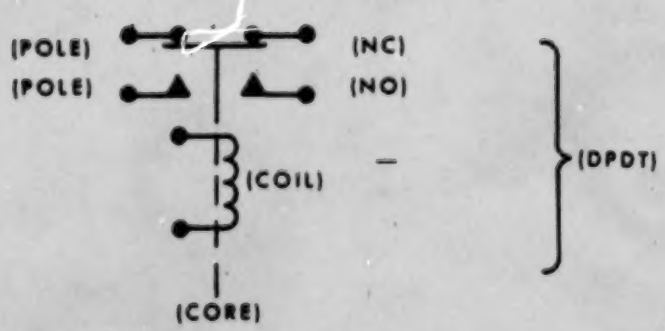
a. SPST b. SPDT c. DPDT d. SPST

800

Frame 24

Did you identify figure "b" in frame 23 as a single pole, double throw relay? If you did, EXCELLENT! This shows you are capable of figuring out these arrangements by simply remembering that the contact where current enters is called a "POLE" and the positions it can be "thrown" to are called "throws." Perhaps you also noted that figure "b" had only one COMMON POLE so that any current entering this pole could be switched to either the upper (NC) contact or the lower (NO) contact depending upon which position the relay is thrown. Take another good look at the figure in frame 18 to see an example of this "common" pole of the single-pole, single throw relay. Here is a problem to stimulate your memory. With the information you have learned so far and the illustration below, underline the word or words that correctly fit the place being pointed to by the arrows.

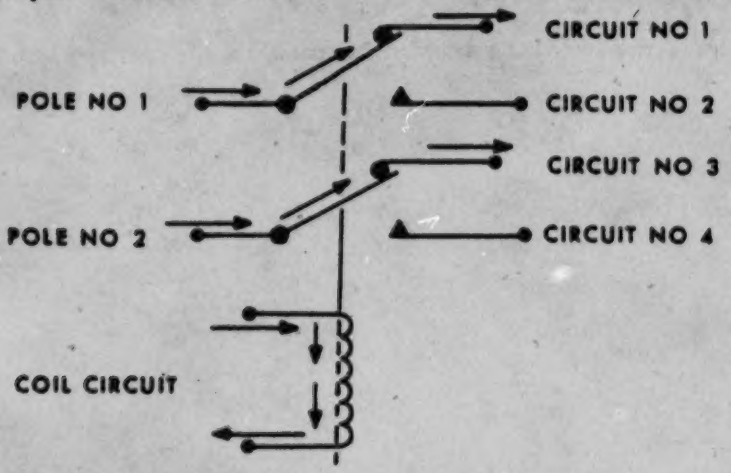




806

Frame 25

Something far too important for us to overlook is how current travels across the relay's contacts. We have shown a DPDT relay in this figure, so you can see the path current flows.



No current travels from Pole No. 1 to circuits 3 and 4 at any time. Pole No. 1 carries current only to circuit 1 or 2. Pole No. 2 carries current ONLY to circuits 3 or 4, NEVER to circuits 1 and 2.

Incidentally, so you won't misunderstand, the actual contacts on a relay will be labeled according to the manufacturer's own desire. We labeled them as shown here so you would know which ones we are talking about in our explanations. It is necessary that you fully understand how current travels from a pole-out through the contacts. Actually, there is some type of insulator between the upper (No. 1) and lower (No. 2) armature poles so that current cannot possibly get from one armature pole to the other. Our relay is made this way so we can CONTROL TWO circuits at the same time with only one switch. Draw a relay circuit that controls two different light bulbs separately. You may use -

1. a switch.
2. a relay.
3. ONE battery.
4. Two lamps.
5. ONLY the CORRECT circuit symbols.

////////////////

Your circuit should closely resemble the illustration in frame 20.

This concludes our presentation of relay construction and operation. It is by no means all you can learn about these wonderful devices. It is enough to enable you to actually wire a relay into a circuit and observe its operation as it controls a lamp.

You will apply what you have learned in the relay PROJECT.

END OF TEXT.

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73-22041

WORKBOOK
3ABR42331-WB-120

Technical Training

Aircraft Environmental Systems Repairman

RELAY SWITCHING CIRCUIT PERFORMANCE

23 August 1978

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Environmental Pneudraulics Branch
Chanute AFB, Illinois

3ABR42331-WB-120

RELAY SWITCHING CIRCUIT PERFORMANCE

OBJECTIVE

Using a DC fundamental trainer, construct a relay switching circuit and measure electrical values with one instructor assist allowed for each task area.

EQUIPMENT

	Basis of Issue
Trainer, P/N 521685	1/student
Multimeter	1/student

SAFETY

CAUTION: Remove watches, rings, bracelets, etc., before starting any work on the equipment. It is also a good safety practice to work on the equipment with one hand. This practice reduces the chances of receiving an electrical shock to some vital body organ when working with electricity. Also remember that light bulbs, resistors, etc., do get HOT and could burn the skin.

PROCEDURE

Pay close attention to all directions that you are given in the workbook. When performing in the workbook, such as answering questions or recording electrical measurements, if your response is incorrect, restudy the information with instructor assistance if needed. Do not hesitate to ask the instructor questions. You will find that many of the exercises have the correct answers on pages 5 and 6. After you have completed all the exercises you will satisfactorily complete the progress check assigned by the instructor. Pages 13 through 15 may, if you wish, be removed for your convenience.

When you leave your trainer for scheduled or unscheduled breaks insure the following are done before you go.

1. Insure the SPST switch is turned OFF in the circuit.

2. Insure the 28 VDC bus bar (red) has all the electrical leads removed from it.

3. Insure the negative (black) bus bar has all the electrical leads removed from it.

4. Insure the multimeter is properly stored during this period.

   a. Insure the controls on the meter are properly set for storage.

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b. Leave the test leads attached to the meter.

c. Wrap the meter leads around the instrument.

d. Place the meter on the locker shelf.

3. When you return from the break take the same meter and go back to work.

Exercise 1

1. Trainer preparation for Exercises 2 through 4.

a. The metal plate on the right side of the trainer may be raised for the workbook to lay on.

b. Sign out a multimeter, see the lab instructor if assistance is needed.

c. Insure that the instructor has connected power to the trainer. You will do this by measuring the power with the multimeter - at the positive (red) and negative (black) bus bar. The bus bars are located in the lower right and left corners of the trainer. If you don't read a voltage (24 VDC $\pm$ 4 VDC) see your instructor.

d. Insure that fuse wire is across the fuse holders of each of the three (3) ammeters on the trainer. This will protect the ammeter internal circuit from overload. If the fuse wire is burned in half or is missing see your instructor for assistance.

e. Pull the circuit breaker out (open) and turn OFF (open) two (2) single pole single throw (SPST) switches.

f. Insure all leads in the drawer are in good condition with a plug at both ends. If you find any damaged leads, give them to the instructor.

g. Examine the electrical lead ends, and note how you may connect them if one lead is too short. See your instructor for assistance if needed.

Exercise 2

2. Build a circuit which controls the relay in a relay switching circuit. This circuit will be made up of one (1) load (the relay coil) with a SPST switch and a circuit breaker.

a. Using the electrical leads from the drawer construct the relay control circuit shown in figure 1 on page 13. This consists of a C/B, SPST switch, and the relay coil.

Note: If an electrical lead is too short you may connect leads together to prevent stretching or breaking them.

b. Before applying power to your circuit, constructed to control the relay, be sure you have the wires hooked up as shown in figure 1.

c. If you study this circuit you will find that the relay coil control circuit is nothing more than a series circuit with the coil as the load.

d. Answer the question below figure 1 on page 13.

Exercise 3

3. This exercise will help you build a circuit which is connected at the relays "NO" contacts. This circuit will be made up of two (2) loads (light bulbs) in parallel, wired through the relays "COM" and "NO" contacts and connected to the C/B.

a. Using the electrical leads from the drawer construct the circuit being controlled by the relay armature, as shown in figure 2 on page 14. This circuit consists of two (2) light bulbs, the relay armature with its contacts, and the C/B.

b. The wire between the "COM" point and the C/B will be connected to the negative side of the C/B. This is the side of the C/B which does not have the wire connected to the bus bar. This way, the C/B can protect all the circuits.

c. If you have correctly wired the circuit you will be able to turn on the lights by moving the SPST switch to ON. Remember, the SPST switch controls power to the relay coil, the current flow through the coil creates a magnetic field, the magnetic field pulls down the armature allowing current to flow through the bulbs.

d. When the SPST switch is opened (OFF), current is cut off to the relay coil, the magnetic field disappears, the armature is pulled up by a spring which cuts off the current flow through the bulbs.

e. Answer the questions below figure 2 on page 14.

Exercise 4

4. This exercise will help you build a circuit which is connected at the relays "NC" contacts. This circuit will be made up of two (2) loads (light bulbs) in series, wired through the relays "COM" and "NC" contacts and connected to the C/B.

a. Using the electrical leads from the drawer construct the series circuit being controlled by the relay armature, as shown in figure 3 on page 15. This circuit is connected to the "NC" contact of the relay and consists of two (2) light bulbs in series, the relay armature with its contacts and the C/B.

b. The wire between the "COM" and the C/B is the same wire you used in exercise 3. You now can see how it serves a dual purpose for the "NC" and the "NO" contacts of the relay. The C/B serves several circuits, the relay coil circuit, the light bulb parallel circuit on the "NO" contacts (exercise 3), and the light bulb series circuit on the "NC" contacts constructed in this exercise.

c. If you correctly wired the circuit in figure 3 you will be able to turn on the light bulbs in the parallel circuit by moving the SPST switch to the ON position, and if you move the SPST switch to the OFF position, you will turn OFF the parallel circuit and turn ON the light bulbs in the series circuit.

d. Also note that when power is applied to the relay coil the light bulbs connect to the "NO" circuit illuminate (light) and if power is cut off to the relay coil the light bulbs connected to the "NC" circuit illuminate.

e. Answer the questions below figure 3 on page 15.

f. If you have any questions about the exercises you have just completed, ask your instructor NOW.

g. Remove all the leads and store them in the drawer and report to your instructor for a progress check assignment.

Correct responses for figures 1 through 3.

FIGURE 1

Total applied voltage 24 VDC ± 4 VDC.

Voltage drop across the relay coil is 24 VDC ± 4 VDC.

1. a
2. a
3. b
4. b
5. b

FIGURE 2

Right lamp 24 FDC ± 4 VDC

Left lamp 24 VDC ± 4 VDC

Voltage drop across the relay coil is 24 VDC ± 4 VDC

Total current flow through only the light bulbs is 3 amp ± 0.4 amp.

1. b
2. a
3. a
4. b

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FIGURE 3

Right lamp 12 VDC ± 2 VDC

Left lamp 12 VDC ± 2 VDC

Total current flow in the light bulb series circuit is 1 amp ± 0.4 amp.

1. b
2. a

PROGRESS CHECK INSTRUCTIONS

This progress check will require you to correctly construct a relay-switching circuit and measure electrical values with one instructor assist allowed for each task area. Instructor assist for each task area is defined as an aid, such as technical direction or explanation given a student, who can proceed no further on his/her own. The instructor will initial your work after you satisfactorily complete each task of the progress check. If you do not pass the progress check you will follow the instructions given by the instructor.

You will not communicate (talk, etc) with other students during the progress check without your lab instructor's permission.

You will not use fellow students work to solve the problems in this progress check.

You must satisfactorily complete this progress check before further progression to other lab progress checks.

Have your lab instructor select and initial on page 6 or 8, the relay-switching circuit progress check you are to draw on the figure on page 10. Using a lead pencil only, draw in the relay-switching circuit leads between the various symbols. Later you will construct this circuit on the trainer. After you have satisfactorily completed the progress check you will follow the instructions on page 11.

_____ Instructor's initials. Assigned progress check 1.

STUDENT'S NAME _____
Last First MI

After completion of each task listed do not progress until the instructor has initialed your work for that task.

TASK 1 - Draw a relay control circuit in the figure on page 10. This circuit will be made up of a C/B, SPST switch, and relay coil.

_____ Instructor's initials for first instructor assist.

_____ Instructor's initials for second instructor assist which is failing.

_____ Instructor's initials for progression.

TASK 2 - Draw a parallel circuit controlled by the relay in the figure on page 10. This circuit will be made of two (2) loads (a light bulb and a 10 ohm resistor) in parallel, wired to the "NO" contact of the relay. Also draw in the power lead between the C/B and the "COM" of the relay. These two (2) loads will share a common ground wire.

_____ Instructor's initials for first instructor assist.

_____ Instructor's initials for second instructor assist which is failing.

_____ Instructor's initials for progression.

TASK 3 - Draw a series circuit controlled by the relay in the figure on page 10. This circuit will be made up of two (2) loads (light bulbs) in series, wired to the "NC" contact of the relay. This series circuit will share the common ground wire used for the parallel circuit above.

_____ Instructor's initials for first instructor assist.

_____ Instructor's initials for second instructor assist which is failing.

_____ Instructor's initials for progression.

TASK 4 - Construct the relay-switching circuit drawn in the figure on the trainer and demonstrate an operations check for the instructor.

_____ Instructor's initials for first instructor assist.

_____ Instructor's initials for second instructor assist which is failing.

_____ Instructor's initials for progression.

TASK 5 - Measure and record the electrical values required below. Take these values from the circuit in the figure on page 10 assigned. Total current flow for only the circuit connected to the "NO" contact of the relay is _____ amps.
Voltage drop across the resistor in the parallel circuit connected to the "NO" is _____ volts.
Voltage drop across the left light in the series circuit connected to the "NC" is _____ volts.

_____ Instructor's initials for first instructor assist.

_____ Instructor's initials for second instructor assist which is failing.

_____ Instructor's initials for progression and satisfactory completion of this progress check.

Turn to page 11 for further instructions.

Note: If the instructor provides an instructor assist for a task, the instructor will initial as required.

_____ Instructor's initials. Assigned progress check 2.

STUDENT'S NAME _____
Last First MI

After completion of each task listed do not progress until the instructor has initialed your work for that task.

TASK 1 - Draw a relay control circuit the figure on page 10. This circuit will be made up of a C/B, SPST switch, and relay coil.

_____ Instructor's initials for first instructor assist.

_____ Instructor's initials for second instructor assist which is failing.

_____ Instructor's initials for progression.

TASK 2 - Draw a parallel circuit controlled by the relay in the figure on page 10. This circuit will be made up of two (2) loads (two (2) light bulbs) in parallel, wired to the "NO" contact of the relay. Also draw in the power lead between the C/B and the "COM" of the relay. These two (2) loads will share a common ground wire.

_____ Instructor's initials for first instructor assist.

_____ Instructor's initials for second instructor assist which is failing.

_____ Instructor's initials for progression.

TASK 3 - Draw a series circuit controlled by the relay in the figure on page 10. This circuit will be made up of two (2) loads (a light bulb and a 10 ohm resistor) in series, wired to the "NC" contact of the relay. This series circuit will share the common ground wire used for the parallel circuit above.

_____ Instructor's initials for first instructor assist.

_____ Instructor's initials for second instructor assist which is failing.

_____ Instructor's initials for progression.

TASK 4 - Construct the relay switching circuit drawn in figure on page 10, on the trainer and demonstrate an operation check for the instructor.

_____ Instructor's initials for first instructor assist.

_____ Instructor's initials for second instructor assist which is failing.

_____ Instructor's initials for progression.

TASK 5 - Measure and record the electrical values required below. Take these values from the circuit in figure on page 10 assigned. Total current flow for only the circuit connected to the "NC" contact of the relay is _____ amps.

Voltage drop across the resistor in the series circuit connected to the "NC" is _____ volts.

Voltage drop across the left light in the parallel circuit connected to the "NO" is _____ volts.

_____ Instructor's initials for first instructor assist.

_____ Instructor's initials for second instructor assist which is failing.

_____ Instructor's initials for progression and satisfactory completion of this progress check.

Turn to page 11 for further instructions.

Note: If the instructor provides an instructor assist for a task, the instructor will initial as required.

812

2500 Ω
500 Ω
10 Ω
10 Ω
10 Ω
10 Ω
VOLTMETER
V
A
A
NC
NO
COM
X1
X2
BLACK
RED
28VDC

After you have satisfactorily completed the progress check you will do the following:

1. Put all the good leads in the drawer of the trainer.

2. Give all the broken leads to the lab instructor with the parts.

3. Place the work table in the down position on the trainer.

4. Return the multimeter to its storage cabinet. Be sure the controls on the meter are set correctly for storage.

5. You will turn in your work to the lab instructor before you leave the lab area.

Note: You may review any part of all of this workbook if you wish, but your work will not leave the lab area without the lab instructor's permission.

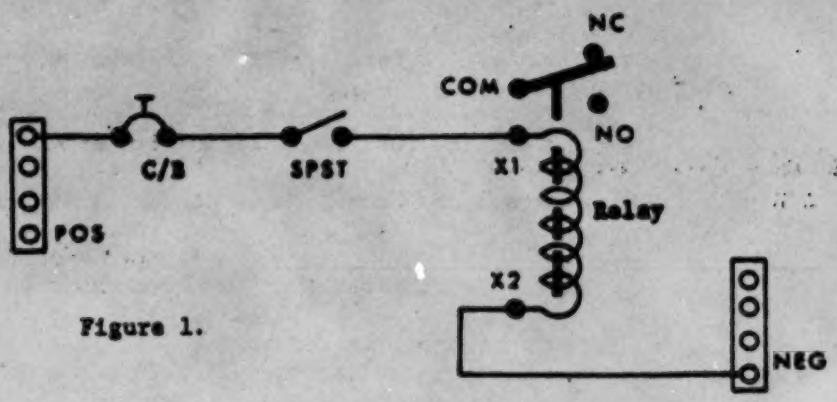

Figure 1.

Total applied voltage _____.

Voltage drop across the relay coil is _____ volts.

Circle the correct answer below.

1. The circuit you have constructed will magnetize the relay coil and cause its armature contacts to be pulled down.

   a. True

   b. False

2. For the relay to operate, BOTH the circuit breaker and the SPST switch must be

   a. closed.

   b. opened.

3. When the relay is turned ON the armature will complete the path between the "common" (COM) pole and the "normally open" (NO) and the "normally close" (NC) contacts.

   a. Yes

   b. No

4. The _____ pulls the armature down.

   a. SPST switch

   b. magnet field

5. The circuit breaker is provided to

   a. permit turning the relay on and off normally.

   b. open the circuit in case the circuit becomes shorted.

Correct answers on page 5.

Go to exercise 3.

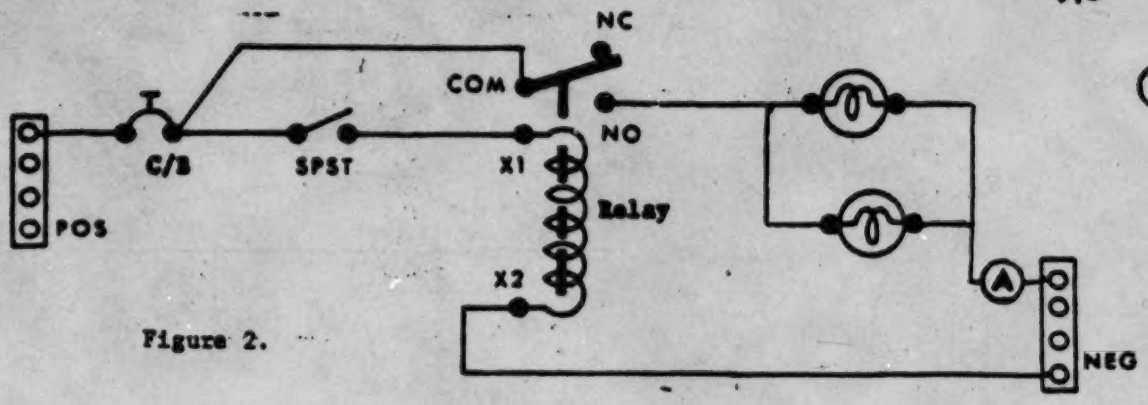

Figure 2.

Voltage drop across the lamps on the trainer. Right lamp _____ volts.

Left lamp _____ volts.

Voltage drop across the relay coil is _____ volts.

Total current flow through only the light bulbs is _____ amps.

1. The two light bulbs in parallel are directly controlled by the
   a. SPST switch.
   b. relay armature.
2. The relay armature is controlled by the
   a. magnetic field.
   b. SPST switch.
3. The magnetic field is controlled by the
   a. SPST switch.
   b. C/B.
4. The SPST switch is controlled by the
   a. C/B.
   b. circuit operator (you).

Correct answers on page 5.

Go to exercise 4.

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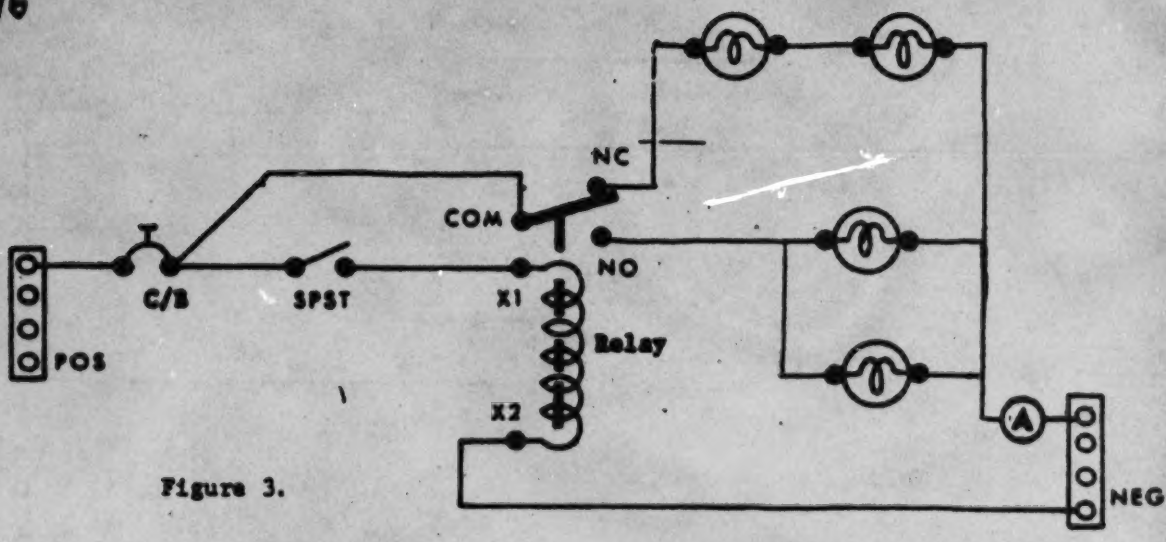


Figure 3.

Voltage drop across the lamps on the trainer in only the series circuit.

Right lamp _____ volts.

Left lamp _____ volts.

Total current flow in the light bulb series circuit is _____ amps.

1. When the SPST switch is in the ON position

   a. all four (4) lights are to light.

   b. only the lights in the parallel circuit will light.

2. The ammeter will show the total current flow in

   a. only the parallel circuit when the SPST switch is ON.

   b. both light bulb circuits and the relay coil circuit when the SPST switch is ON.

Correct answers on page 6.

Go to exercise 4, step "f".

822

Technical Training

Aircraft Environmental System Mechanic

DC MOTORS

19 July 1974

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR42231-PT-118, 3ABR42230-PT-209, 22 February 1972.
OPR: TAS
DISTRIBUTION: X
TAS - 150; TTOC - 2

Designed For ATC Course Use

DO NOT USE ON THE JOB

818

FOREWORD

This programmed text was prepared for use in the 3ABR42330 and 3ABR42331 instructional systems. The material contained herein has been validated using 37 students enrolled in each of the subjects course. Ninety percent of the students taking this text achieved the objectives. The average student required 71 minutes to complete the text.

OBJECTIVE

Given 10 characteristics of DC motors, match 70% correctly as being characteristics of either a series or a shunt motor.

INSTRUCTIONS

NOTE: BEFORE PROCEEDING, REMOVE THE RESPONSE SHEETS AT THE BACK OF THIS TEXT. THEN ENTER YOUR ANSWERS ON THE REMOVED SHEETS.

This programmed text presents information in small steps called "frames." After reading each frame, you are expected to respond by supplying a word or words, to complete a statement, choose either TRUE or FALSE, select the correct answer, or match terms to their proper meaning. DO NOT MARK IN THIS TEXT.

Use a piece of paper or card as a mask to cover the printed materials. Slide the paper or mask down the page until you expose the row of slashes (//////////////////). One small step is now exposed for you to read. Read the material presented, select your response to the question, and indicate your response on the response sheets. After you respond to the question, slide the mask down and compare your answer with the one given in the text. If you are correct, go on to the next frame. If your answer is wrong, read the frame again.

Frame 1

Mechanical energy which has been converted from electrical energy is used in many different applications. You will be working on equipment that contains some form of energy conversion. Therefore, an understanding of the devices providing energy conversion are essential if you are to become good in your field.

There are many devices which convert energy. Our discussion will be limited to a device which changes electrical energy into mechanical energy, the motor. Motors are normally classified according to the voltage or current used, that is, AC or DC. In this text we will discuss the series and shunt DC motors.

//

No Response Required

Frame 2

As you have already learned, a magnetic field exists around any current-carrying conductor. The strength of this magnetic field depends upon the amount of current flowing in the conductor. When this current-carrying conductor is placed in a fixed magnetic field, the reaction of the two magnetic fields will cause the conductor to move out of the fixed field. The amount and direction of this force resulting from the interaction between the conductor's magnetic field and the fixed magnetic field determines the speed of the motor and its direction of rotation. All motors operate on the same fundamental principle, the force exerted on the current-carrying conductor when it is placed in a magnetic field.

Check the following statements that are TRUE.

1. A magnetic field exists around all current-carrying conductors.

2. The strength of the magnetic field around a current-carrying conductor depends upon the amount of current flow in the conductor.

3. The fundamental principle of operation of any motor is that force is exerted on a current-carrying conductor when placed in a magnetic field.

820

Answers to Frame 2: ___1. ___✓2. ___✓3.

Frame 3

The force which acts on the current-carrying wire (conductor) when it is placed in the field of a magnet is at right angles to the wire. It is also at right angles to the magnetic field set up by the magnet. The action of this force upon the current-carrying conductor is shown below. The illustration shows a wire located between the magnet's poles. The lines of force in the magnetic field are from the north pole to the south pole (externally). When no current flows no force is exerted on the conductor.

WIRE WITHOUT CURRENT
LOCATED IN A MAGNETIC FIELD

Complete the following statements.

1. A _____ field exists around any current-carrying conductor.

2. Unless current is flowing within a conductor, no _____ is exerted upon it, even when in a magnetic field.

826

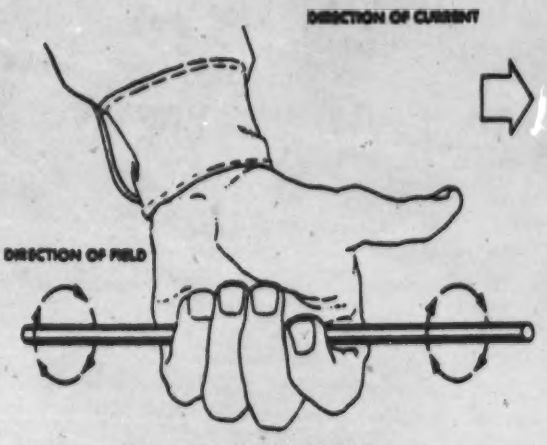
Frame 4

When current flows through the conductor, a magnetic field is set up about it, as is shown in the illustration.

WIRE WITH CURRENT AND ACCOMPANYING FIELD

The direction of the field around the current-carrying conductor depends on the direction of current flow. Current in one direction creates a clockwise field about the conductor. Current in the other direction creates a counterclockwise field.

Do you remember the rule for determining direction of rotation of the magnetic field? The rule states "Grasp the conductor in the left hand. The thumb points in the direction of current flow. The fingers will point in the direction of the magnetic lines of force around the conductor."



LEFT HAND THUMB RULE

Study the diagram above and answer the following question.

With current flowing through the conductor in the direction of the arrow, (you are standing at the left end of the conductor looking towards the right end) the magnetic field will rotate in a direction?

(Counterclockwise) (Clockwise)

822

Answer to Frame 4: Counterclockwise

Frame 5

The force which acts upon the current-carrying conductor when it is placed between the poles of the magnet will drive the conductor out of the field. The direction of this force is shown below. Note that the magnetic lines of force below the conductor are in the same direction as the lines of force around the conductor. These two forces add and strengthen the magnetic field below the conductor. The lines of force above the conductor oppose the magnet's lines of force. This action weakens the magnetic field above the conductor. The combination of the strong field below the conductor and the weak field above the conductor produces force which drives the conductor up. The conductor is always pushed away from the side where the field is strongest.

RESULTANT FIELD AND DIRECTION OF FORCE ON WIRE

Identify the following statements as true (T) or false (F).

1. A current carrying-conductor placed between the poles of a magnet is not affected by the magnetic field.

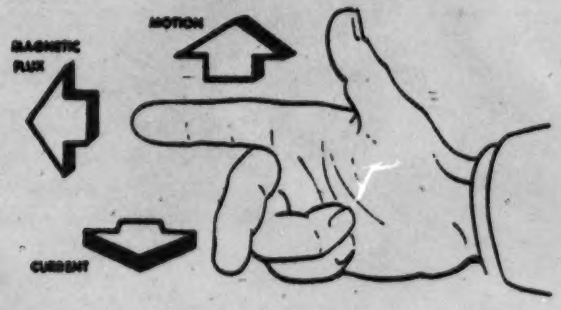
2. With current flowing as shown in the illustration, the conductor will be pushed up.

//

F 1. T 2.

828

If the current flow through the conductor were reversed in direction, the two fields would add at the top and subtract at the bottom. Since a conductor is always pushed away from the strong field, the conductor would be pushed down. The direction of motion can be determined easily as the following illustration shows. Don't confuse this rule with the left hand rule which is used to determine the polarity of a coil. This is called the Right Hand Motor Rule and states "Point the index finger of the right hand in the direction of the magnet's external magnetic field (N to S). The second finger pointed in the direction of current flow. The thumb will indicate the direction of motion."



Complete the following statement.

The Right Hand Rule is used to determine the direction of conductor _____.

//

Motion

Frame 7

We now know how a current-carrying conductor moves in a magnetic field. Let's determine how this action is put to use in a motor. Although DC and AC motors operate on the principle just explained, they use different methods in obtaining a magnetic field and conductor current. For this reason let's discuss the basic DC motor before covering the basic AC motor.

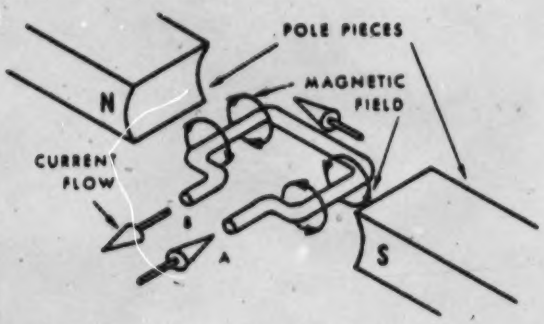
//

No Response Required

824

Frame 8

If the single conductor is bent into a loop, the loop will tend to rotate in the field between the magnets. In the loop shown below, current flow is inward on side "A" and outward on side "B". The magnetic field about "B" is clockwise. The magnetic field about "A" is counterclockwise. With the single conductor, in which current flowed inward, a force will develop which pushes "B" downward. Current flow in the field of the magnet and the field about "A" is inward. The magnetic field will add at the bottom and subtract at the top. You can prove this by the Right Hand Motor Rule, "A" will move upward. The loop (A and B) will rotate until both sides are outside of the magnetic lines between the north and south poles of the magnet. In this position no torque (twisting force) is produced and the loop remains stationary instead of turning over.



Identify the correct words to complete the following statement.

With current flow as shown in the diagram above, the magnetic field will be (strongest) (weakest) above B and below A, causing the loop to rotate (clockwise) (counterclockwise).

//

strongest counterclockwise

Frame 9

Let's summarize what we've learned in the preceding frames by identifying the following statements as true (T) or false (F).

1. When current flows through any conductor, a magnetic field is set up about the conductor.

2. If a current-carrying conductor is placed between the poles of a magnet, the two magnetic fields cancel each other.

3. The direction of current flow within a conductor determines the direction of the magnetic field about it.

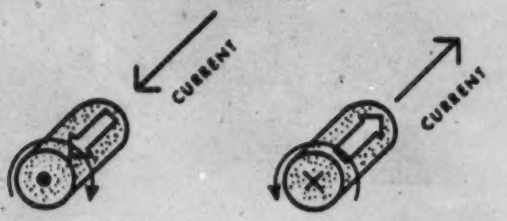
4. The direction in which a conductor is forced out of the magnetic field can be determined by using the Right Hand Motor Rule.

Answers to Frame 9: 1. T 2. F 3. T 4. T

Frame 10

It is general practice to draw a cross representing current flowing away from you in a conductor. A dot represents current flowing toward you.

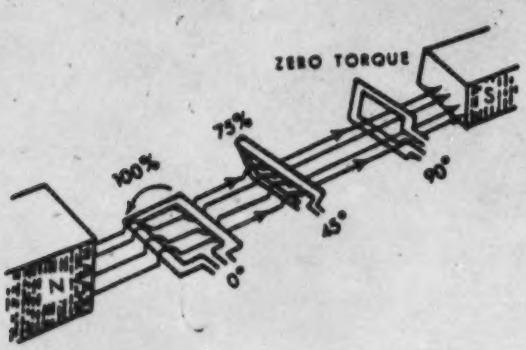
Study the illustration to become familiar with this method of showing direction of current flow through a conductor.



No Response Required

Frame 11

When the loop is parallel to the magnetic field as shown at 0° in the following illustration torque is maximum. Maximum torque occurs at this position. In this position the force acting upon the coil is in the same direction as coil movement. In any other position, however, only a portion of the force is in the direction of coil movement.



Complete the following statement.

Maximum torque occurs when the coil is in the position labeled _____.

(0°) (90°)

(0°)

Torque on a coil at various angles of rotation.

826
Frame 12

As the loop approaches the neutral plane of 90° (refer to frame 11), torque decreases. If the loop has sufficient "inertia," (a tendency to keep moving as a flywheel would) it will swing past the neutral plane, as shown in figure 1.

When loop side A swings to the right side, and loop side B swings to the left of the neutral plane, torque reverses. The loop will attempt to reverse its direction of rotation.

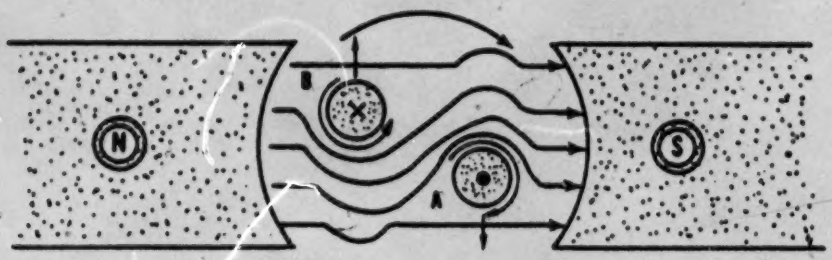


Figure 1.

Notice in figure 2, loop side A is to the left of the neutral plane. The current through it causes a counterclockwise torque. The current through loop side B to the right of the neutral plane is in the opposite direction. It also causes a counterclockwise torque. To keep torque in a counterclockwise direction, the current through the loop side to the left of the neutral plane must always flow out of the page (•). The current on the right of the neutral plane must always be into the page (x). To maintain continuous rotation some means must be provided which will reverse the direction of current through the loop as it rotates past the neutral plane.

Figure 2.

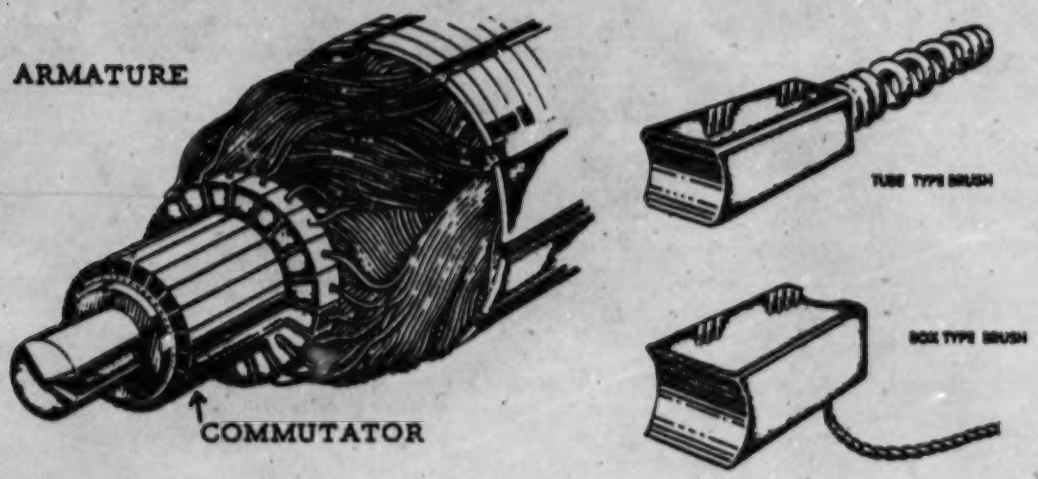
Is the following statement TRUE or FALSE?

In order for the loop to rotate counterclockwise, the current through both sides of the loop must be in the same direction.

//

False
8 832

This current reversal is accomplished by use of brushes and a commutator. A commutator is made up of a number of copper segments separated by insulating spacers. The number of segments depends upon the number of loops placed in the magnetic field, the type of coil winding used, and the voltage applied to the coils. Each segment is connected to a coil. The coils are wound so their sides are 180° apart.



Complete the following statement.

The procedure of reversing current is accomplished by using _____ and a _____.

//

brushes commutator

828

Frame 14

Complete the following statements.

1. In a diagram showing current flow in a conductor, a dot (•) indicates that current flow is _____ (into, out of) the page.

2. Maximum torque occurs when a coil is _____ (inside of) (outside of) the magnetic field.

3. In order to maintain continuous rotation of a coil, current flow must _____ (reverse-not reverse) in direction within the coil as it sweeps past the neutral plane.

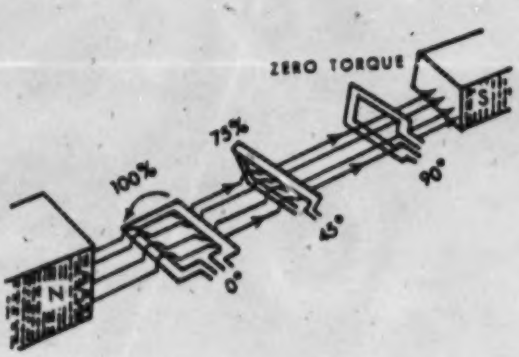
4. Each segment of a commutator is connected to a _____ (coil-brush).

//

1. out of 2. inside of 3. reverse 4. coil

Frame 15

The amount of torque developed in a coil depends upon several factors--the strengths of the two reacting magnetic fields, and the position of the coil in the field. Let's take another look at the different positions of the coil (loop). In a coil carrying a steady current located in a uniform magnetic field, the torque will vary at different positions of rotation. When the coil is parallel to the lines of force, such as at 0°, the torque is maximum. When it is at 90°, the torque is at minimum. At other positions the torque ranges between zero and maximum.



Torque on a Coil at Various Angles of Rotation.

Study the illustration and answer the following question.

With current flow and force in the direction as shown, the conductor will rotate in a direction?

(clockwise) (counterclockwise)

//

Counterclockwise

When a loop (conductor) is rotated in a magnetic field, a voltage is induced in each side of the loop, see figure 1. During rotation, the two sides (A and B) of the loop cut the magnetic flux lines in opposite directions. Although the current flow is continuous in the loop, it moves in opposite directions with respect to the two sides A and B. To check this, apply the right hand rule, as shown in figure 2, to A and B in figure 1. Comparing wires A and B. When the loop rotates half a turn, the wires have exchanged positions. The induced EMF within each wire has reversed its direction. When two magnetic poles are used, the induced voltage reaches its peak value and reverses its direction twice per revolution. As a motor changes electrical energy to mechanical motion, it is at the same time generating a voltage (EMF) because it moves through the magnetic field.

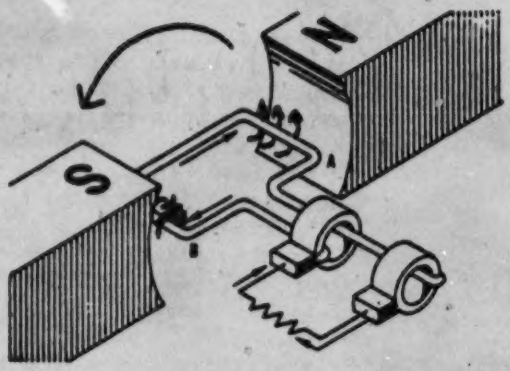


Figure 1. Voltage Induced in a Loop Conductor.

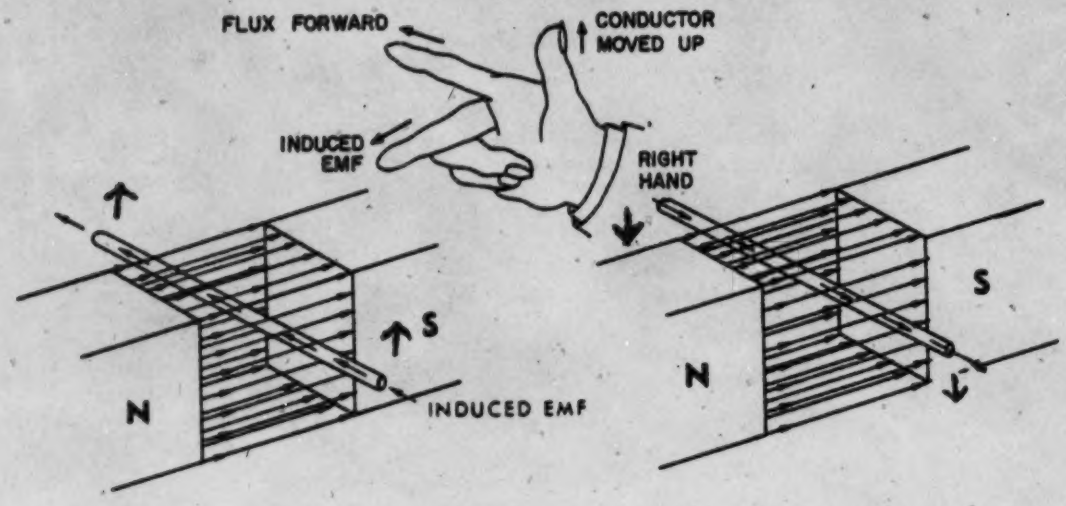


Figure 2. Left Hand Rule.

The action of the induced EMF will always oppose the applied EMF in a motor armature. This action called counterelectromotive force (CEMF). The CEMF tends to decrease the applied EMF on the armature. This in turn decreases the total armature current.

Is the following statement TRUE or FALSE?

Counterelectromotive force (CEMF) always has the same polarity as the applied EMF.

//

False

11

830

Frame 17

As the CEMF gets nearly as large as the applied armature voltage the armature current decreases. Very little current is required to keep a motor running without a load, just enough to overcome electrical losses and friction. If a greater load is put on the motor, the motor will slow down. This reduced speed causes the motor to generate less CEMF. Since there is now less CEMF (induced voltage) the applied current will be allowed to increase. The increase in current develops a greater torque to make up for the increased load. Since the applied voltage remains constant, there is a definite speed for each change of load. The greater the load the lower the speed. The CEMF is the controlling factor in speed and torque regulation of a motor.

Select either TRUE or FALSE for the following statements.

1. From our discussion of counterelectromotive force (CEMF) we can say that CEMF is induced voltage or current in the armature.

2. Counterelectromotive force is always opposite in polarity to the applied EMF.

3. CEMF is the controlling factor in the regulation of the speed of a motor.

//

T 1. T 2. T 3.

Frame 18

As we begin to discuss the different types of DC motors, let's first cover the major parts of a basic DC motor. These major parts are the armature assembly, the field assembly, the brush assembly, and the end frame.

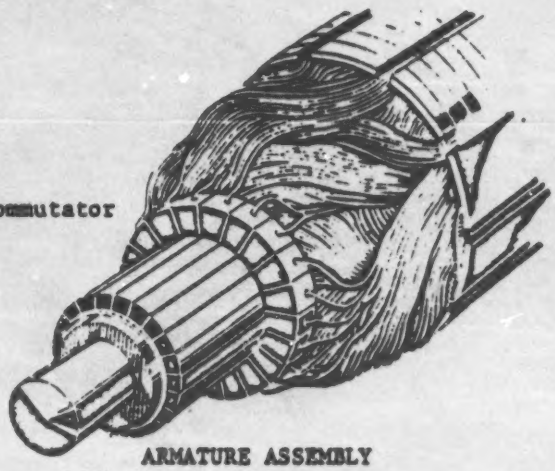
These will be discussed separately in the following frames.

//

No Response Required

836

The armature assembly contains a laminated soft iron core, coils, and a commutator, all mounted on a steel shaft. Laminations--layers of soft iron, insulated from each other--form the armature core. Solid iron is not used, since a solid iron core revolving in the magnetic field would heat and use energy needlessly. The armature windings are made of insulated copper wire. They are inserted in slots which are insulated to protect the windings. The ends of the windings are connected to the commutator segments. Wedges or steel bands hold the windings in place to prevent them from flying out of the slots when the armature is rotating at high speeds. The commutator is made up of an even number of copper segments insulated from each other and from the armature shaft by pieces of mica.



ARMATURE ASSEMBLY

Complete the following statements.

1. A soft iron core, coils, and a commutator make up the _____ assembly.

2. The ends of the windings are connected to the _____ _____.

3. The commutator is made up of an (even) (odd) number of copper segments.

1. armature 2. commutator segments 3. even

Frame 20

The field assembly consists of the field frame, the pole pieces, and the field coils. It contains laminated soft steel pole pieces on which the field coils are wound. A coil, consisting of several turns of insulated wire, fits over each pole piece. Together with the pole, it makes up a field pole. It is this field assembly that takes the place of a natural magnet such as we have used in previous illustrations. By winding the field pole we form an electromagnet.

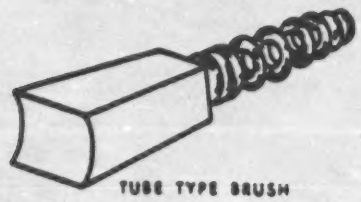
Identify the parts that make up the field assembly.

1. _____ 2. _____ 3. _____

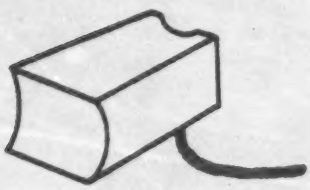
1. pole pieces 2. field coils 3. field frame

832
Frame 21

The brush assembly contains the brushes and their holders. The brushes are usually small blocks of carbon. This material lasts a long time and doesn't wear the commutator out as quickly as other materials might. The holders permit some play in the brushes so they can follow any irregularities in the surface of the commutator and thereby make good contact at all times. Springs hold the brushes firmly against the commutator.



TUBE TYPE BRUSH



BOX TYPE BRUSH

Complete the following statement.

Brushes are usually made of _____ to reduce wear on the _____.

carbon commutator

Frame 22

The end frame is the part of the motor on the opposite end from the commutator. The end frame is usually designed so that the motor can be geared on that end to the unit it will be turning. The bearing for the drive end is located in the end frame. Sometimes the end frame is made a part of the unit driven by the motor. When this is done, the bearing on the drive end may be located in any one of a number of places.

Select TRUE or FALSE for the statements.

____1. The bearing for the drive end is located in the end frame.

____2. The end frame is a part of the commutator.

____3. The motor is usually geared to the unit drive on the end frame.

T 1. F 2. T 3.

Match the units listed in the left hand column below to the major part of a DC motor to which they belong in the right hand column.

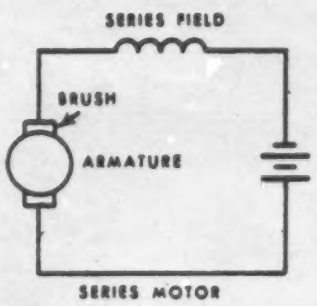
1. Coils, commutator, and soft iron core.	a. End frame.
2. Brushes and brush holders.	b. Field assembly.
3. Bearings.	c. Armature assembly.
4. Pole pieces, field coils and field frame.	d. Brush assembly.

//

1. c 2. d 3. a 4. b

Frame 24

The first type of DC motor which we shall discuss is the series motor. A series motor has its field winding connected in series with its armature. This method of connection makes it necessary for the field to be heavy enough to carry the armature current. Due to the series connection, the field winding is composed of relatively few turns of heavy wire in order to carry the relatively high armature current. The same current that flows through the field winding also flows through the armature winding. Therefore, any change in armature current is accompanied by a change in field strength.



Select the letter for the statement which completes the following statement.

In a series motor, the field winding

a. is connected in series with the commutator.

b. consists of a few turns of fine wire.

c. is connected in series with the armature winding.

d. has a separate power source.

//

c

834

Frame 25

When voltage is first applied to a series motor, a high starting current flows and a large starting torque is developed. The large starting current is due to the absence of CEMF, and the low resistance of the armature. As soon as the developed torque becomes great enough, the armature starts into motion. It accelerates toward its normal running speed.

Are the following statements TRUE or FALSE?

1. Because of the low resistance in the windings, the series motor draws a large current when starting.

2. In passing through both the field and armature windings, the starting current produces a high starting torque.

//

1. TRUE 2. TRUE

Frame 26

After getting started, armature current begins to decrease as an increasing CEMF is induced into the armature. This decrease in armature current also decreases motor field strength. This in turn attempts to decrease CEMF. Due to this action the series motor continues to accelerate in an attempt to maintain CEMF and limit armature current to a safe value. If the motor is not connected to a load, it attempts to operate at a very high speed which may result in motor damage. For this reason, series motors are never operated without a load.

From the foregoing statements, select either TRUE or FALSE for the following:

A series motor will run at high speed when it has a light load and at a low speed with a heavy load.

//

True

Frame 27

A series motor will slow down when its load is increased, due to the increased opposition to armature movement. The decreased CEMF caused by the decrease in motor speed results in an increase in armature current. The increased armature current provides the additional torque required by the increased load. A series motor, because its field strength depends upon armature current, requires a large variation in speed for a relatively small change in torque. Remember that an increase in armature current is the result of a decrease in speed. This also increases field strength which tends to decrease speed.

Complete the following statement.

An Increase in armature current is the result of a decrease in armature Speed.

//

increase speed

Frame 28

Direction of rotation for a series motor may be changed in one of two ways:

1. Reversing current flow in the field winding. or

2. Reversing current flow in the armature.

When either of these currents is reversed, motor torque reverses and the direction of rotation reverses. Direction of rotation cannot be reversed by reversing the power source leads. This action would reverse current flow in both the armature and field windings. When both these currents are reversed, torque remains in the same direction and motor rotation remains unchanged.

An exception to this is the small motor with a permanent magnet for a main field. In this case reversing the power source leads only reverses current through the armature windings and not the main (permanent magnet) field.

Identify two ways by which direction of rotation may be changed.

1.

2.

//

1. Reversing direction of current flow in the field winding.

2. Reversing direction of current flow in the armature winding.

Frame 29

To review what has been covered in the last few frames, select either TRUE or FALSE where needed, or complete the statement.

1. In a series motor, the field winding and the armature windings are connected in series.

2. The large starting current produces a high starting _____.

3. The heavier the load applied to the series motor, the faster the speed.

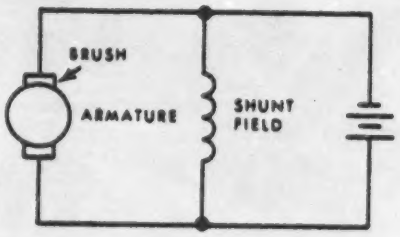
4. The field strength of a series motor depends upon armature and field _____.

//

1. T 2. torque 3. F 4. current

836
Frame 30

Another type of DC motor is the shunt motor. In this type of motor, the field winding is connected in parallel (shunt) with the armature winding. There are two circuits through the shunt motor--one through the armature and one through the field. The field coils are wound with relatively small wire and have a large number of turns. In this type of winding only a small current flow is necessary to maintain the magnetic field. Because the field is connected directly across the power supply the magnetic field remains constant. Therefore, the torque of a shunt motor must vary with the current in the armature; that is, if the armature current doubles, the torque is also doubled. Since the field strength is constant, the motor speed will be constant from no load to full load. The shunt-wound motor is a constant speed type, but because of fixed field current, it does not have a starting torque as high as the series motor.



SHUNT MOTOR

Is the following statement TRUE or FALSE?

The shunt motor, like the series motor, has a high starting torque.

//

False

Frame 31

Small shunt motors may be started simply by connected voltage to them. The field current and field flux rise quickly to their full value. The armature current also rises rapidly since CEMF is zero when the armature is stationary. When the developed torque is great enough to overcome the friction and inertia of the armature and load, the armature starts into motion. CEMF proportional to motor speed is induced in the armature. The CEMF causes armature current to drop rapidly as the motor accelerates. Armature current becomes constant when motor speed becomes constant.

Complete the following statements.

1. The CEMF causes armature _____ to drop rapidly as the motor speeds up.

2. A shunt motor has two circuits--one through the _____ and one through the _____.

//

1. current 2. armature 3. field

Frame 32

The field strength of the shunt motor remains constant. The operating characteristics are quite different from those of the series motor. The shunt motor has:

1. Low starting torque.

2. Good speed regulation.

The low starting torque does not mean the shunt motor cannot be started with a load. Instead, it indicates that given a series and shunt motor of equal size and horsepower, the series motor produces greater starting torque.

1. Which type of motor, the series or shunt, produces the greater starting torque?

2. Which type of motor, the series or shunt, has the better speed regulation?

//

1. Series motor 2. Shunt motor

Frame 33

A shunt motor's direction of rotation is changed in the same manner as the series motor, which is:

1. Reversing current flow in the armature. or

2. Reversing current flow in the field winding.

//

No Response Required

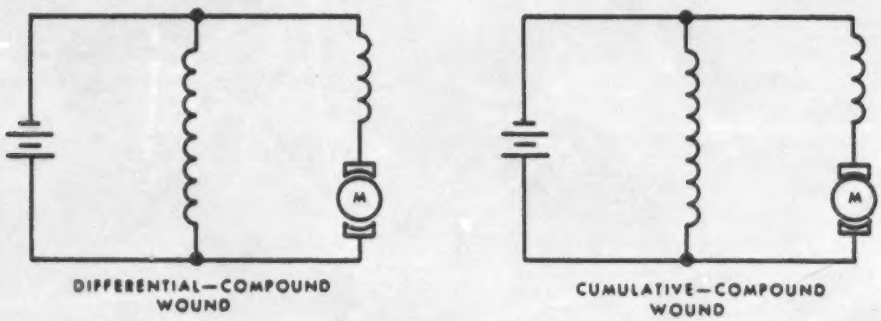
838

Frame 34

In addition to the series and shunt motors there are also compound motors. We won't go into a lengthy discussion of these motors other than to point out the different types of compound motors.

CUMULATIVE-compound motors have both a series and a shunt field which are connected so that the series windings aid the shunt field. This motor combines the characteristics of series and shunt motors. It is normally used when a starting torque greater than that of a shunt motor and a fairly constant speed are desired.

DIFFERENTIAL-compound motors are similar to cumulative-compound motors in all respects except the field windings. In this type of motor the fields are arranged so that the series fields oppose the main shunt field. This weakens the main field and tends to increase the speed of the motor as the load is increased. Due to this opposition, the field strength decreases as armature current increases.



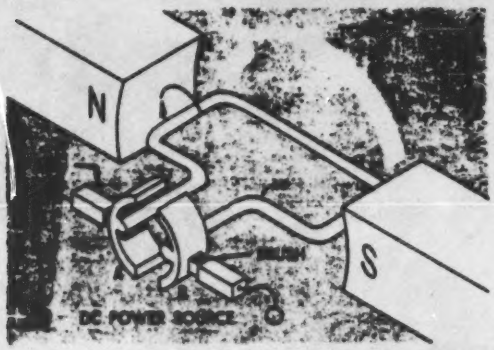
DIFFERENTIAL—COMPOUND WOUND

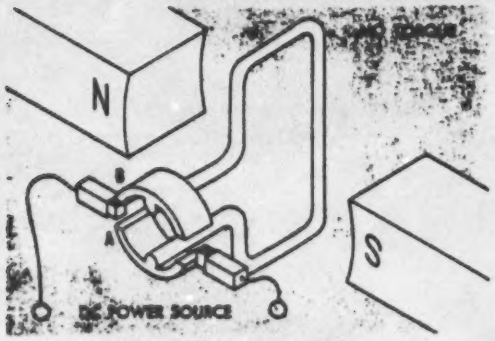
CUMULATIVE—COMPOUND WOUND

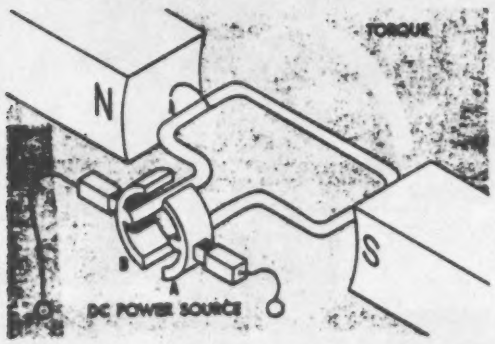
No Response Required

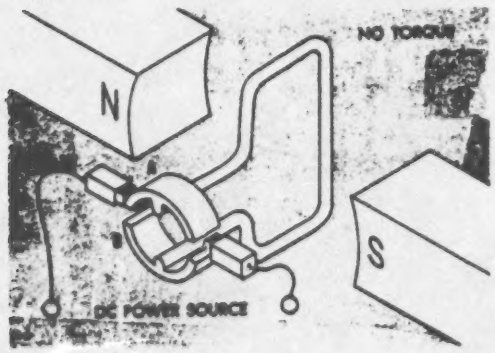
844

The accompanying diagrams show the operation of a typical DC motor. As you study these diagrams, recall the theory of operation as was explained in the preceding frames.









If any of these illustrations raise the slightest question, go back to the frames that explain the area in which you are having difficulty.

No Response Required

840
Frame 36

At this point you have learned some of the differences associated with the DC motors.

Match the letter of the motor types on the right with the DC motor characteristics on the left.

1. Field winding connected in parallel with the armature.
2. Field winding has only a few turns of heavy wire.
3. Poor speed regulation.
4. Torque varies with current in the armature.
5. Has low starting torque.
6. Has highest starting torque.
7. Good speed regulation.
8. Large current when starting.
9. Magnetic field remains constant.
10. Must operate under a load.

A. Series motor.

B. Shunt motor.

//

1. B 2. A 3. A 4. B 5. B 6. A 7. B 8. A 9. B 10. A

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WORKBOOK
3ABR42331-WB-121

Technical Training

Aircraft Environmental Systems Mechanic

DC MOTOR AND CONTROL CIRCUIT WIRING DIAGRAMS

7 August 1979

CHANUTE TECHNICAL TRAINING CENTER (ATC)
3370 Technical Training Group
Chanute Air Force Base, Illinois

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DC MOTOR AND CONTROL CIRCUIT WIRING DIAGRAMS

OBJECTIVES

Using an electric diagram, identify a minimum of 8 out of 10 circuit malfunctions when given the cause and the circuit condition.

EQUIPMENT

	Basis of Issue
Color Pencils Set	1/student

INSTRUCTIONS

Pay close attention to all directions that you are given in the text. When performing in the text, such as tracing or answering questions, if your response is incorrect, restudy the information. At the end of this workbook, you will have a progress check, which will be graded by your instructor. If you are ready to begin, and have no questions, proceed with the lesson.

Exercise 1

1. Using a RED pencil, trace the following voltage sources on figure 1.

a. Trace from the bus bar through the circuit breaker (CB No. 1) along wire H1A18 to pole A1. With the circuit breaker (CB) pushed in (closed), there will be a voltage potential (28V DC) up to pole A1.

(1) Voltage stops at A1 because relay #1 (R1) has not been energized. The spring attached to the armature contact is holding it away from contact A2 of R1, thereby breaking the electrical circuit between points A1 and A2 of relay #1 (R1). Relay R1 is called the close relay.

b. Trace from the bus bar through the circuit breaker (CB No. 2) along wire H5A18 to the pole of the control switch. With the circuit breaker (CB) closed there will be a voltage potential up to the pole of the control switch.

(1) Voltage stops at the pole unless the switch is placed (moved) to either the OPEN or CLOSE position.

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c. Next trace from the bus bar through CB No. 3 along wire H2A18 to pole A1. With the CB closed there will be a voltage potential up to this point.

(1) Voltage stops at this point because R2 has not been energized. The spring attached to the armature contact is holding it away from contact A2 of R2, thereby breaking the electrical circuit between points A1 and A2 of relay #2 which is called the OPEN relay.

d. Now trace from the bus bar through CB No. 4 across wire H7A18 to the pole of the TRANSFER switch. With the circuit breaker closed and the TRANSFER switch in the OFF (open) position there will be a voltage potential up to the switch.

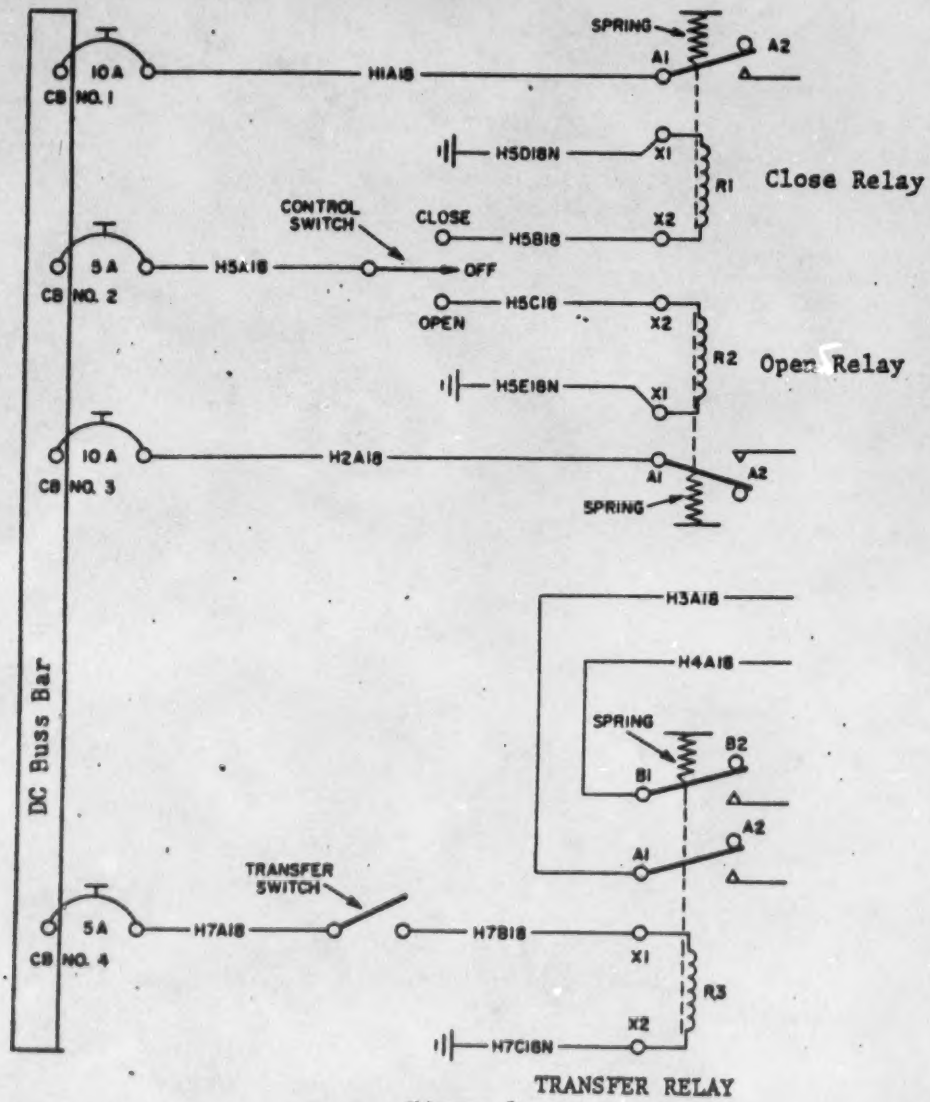
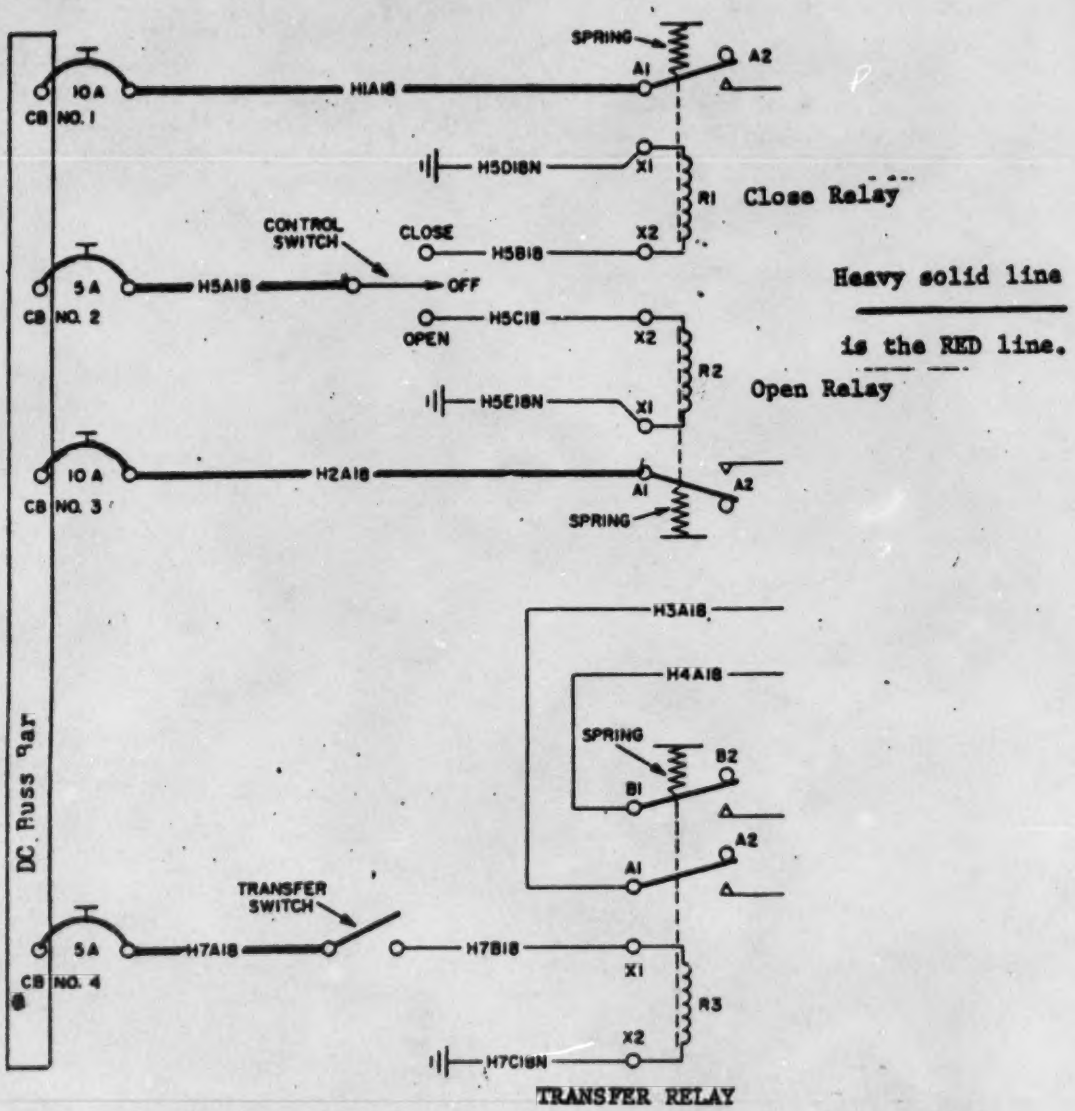


Figure 1.

After tracing the above diagram, turn the page and compare the diagram that you have traced with the diagram on the following page.

Confirmation for Exercise 1:

The bold lines in the diagram below indicate the circuit that you should have traced.



If your diagram was correct, continue the exercises. If not, see your instructor.

Exercise 2

1. Using an ORANGE pencil, trace the power on TRANSFER relay circuit in figure 2.

a. Start from the voltage potential which is on the pole (left side) of the transfer switch. Trace through the switch across wire H7B18 to point X1 of the TRANSFER relay (R3), through the coil of the relay to X2, then along wire H7C18 to the common ground point. As soon as the switch is turned on, you would send power over to X1 of relay R3 coil.

(1) Relay R3 is now energized. By the term "energized" we mean that the relay coil becomes a temporary magnet. With relay R3 energized the relay armature contacts between B1 to B2, and A1 to A2 will be pulled down toward the magnetized relay coil. The magnet is strong enough to overcome the spring tension that normally holds the armature contacts away from contacts B2 and A2 of R3. Relay R3 is called the TRANSFER relay.

Note: The vertical dotted lines (running up and down) going through the relay coil up to and through the armature contacts A1 and A2, B1 and B2 indicates that when the relay becomes a magnet anything connected to the dotted lines will be pulled toward the magnet. When the coil is not magnetized (without current flow in the coil) the springs connected to armature pull them away from B2 and A2 contacts. The dotted line indicates mechanical linkage is used to pull the armatures down.

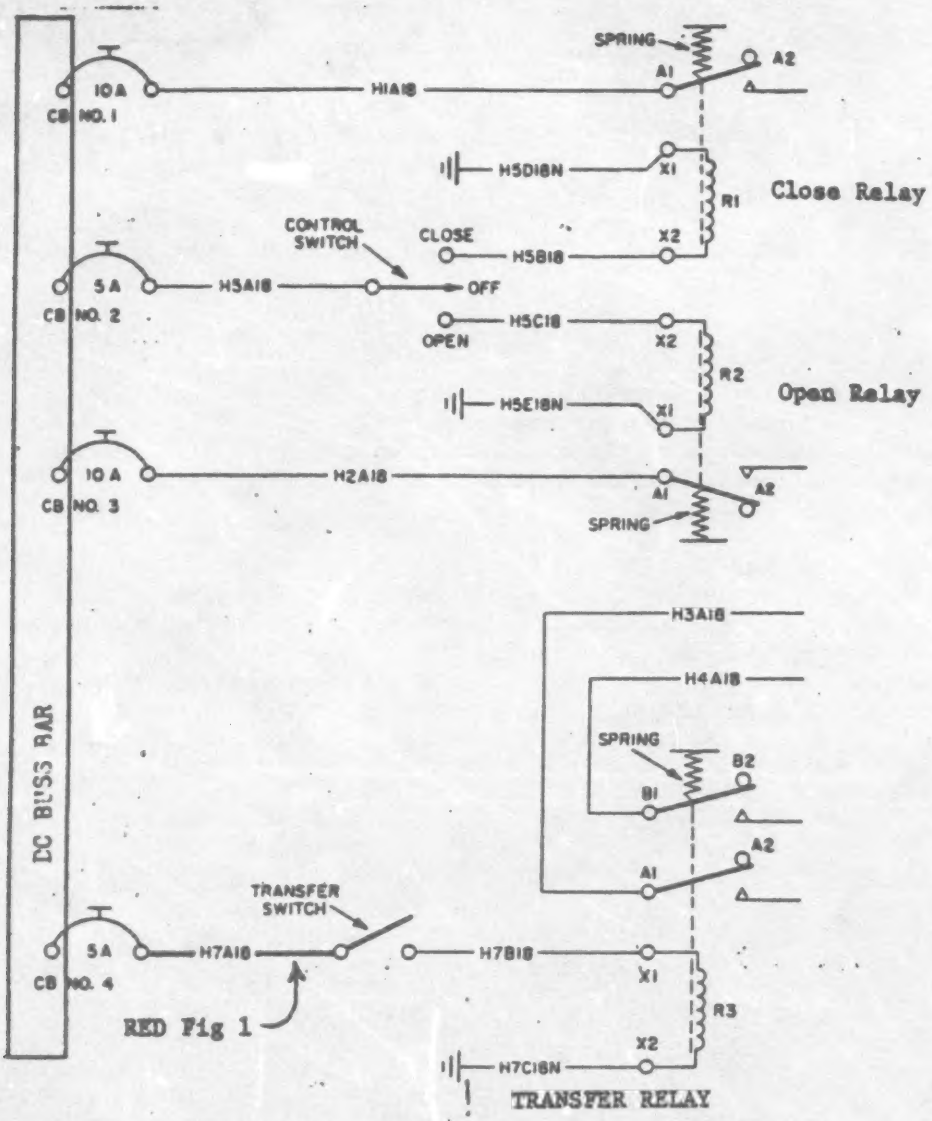
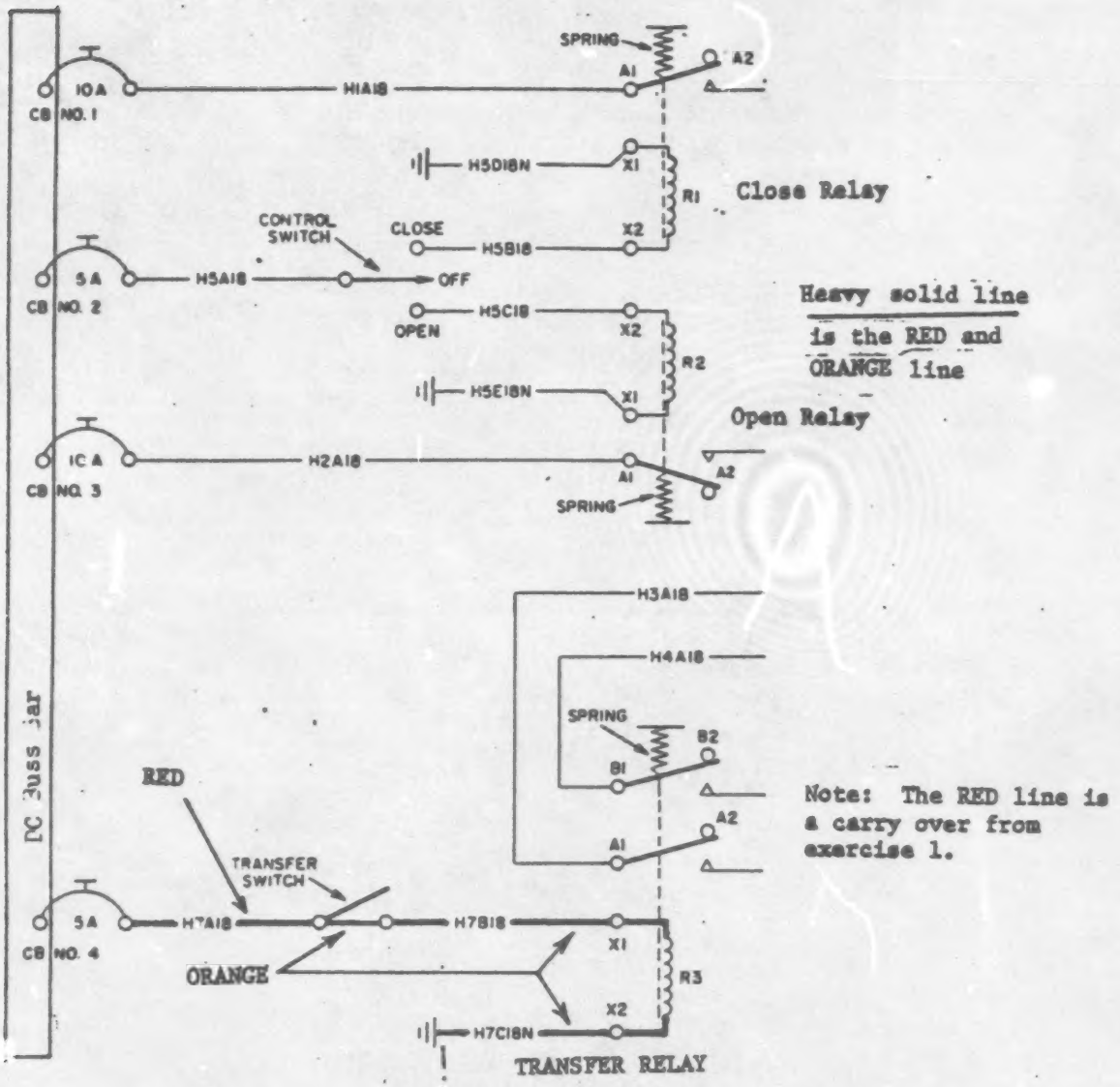


Figure 2.

After tracing the above diagram, turn the page and compare the diagram that you have traced with the diagram on the following page.

Confirmation for Exercise 2:

The bold lines in the diagram below indicates the circuit that you should have traced.



If your diagram was correct, continue the exercises. If not, see your instructor.

Exercise 3

1. Using a BROWN pencil, trace the armature contacts of relay 3 to their energized position (DOWN, B1 to B2, A1 to A2) on figure 3.

a. Remember: When the relay is "not energized" the spring holds the armature contacts to the OPEN position. When the relays are energized the magnetic field strength overcomes the spring tension and pulls the armature contacts toward the relay coils.

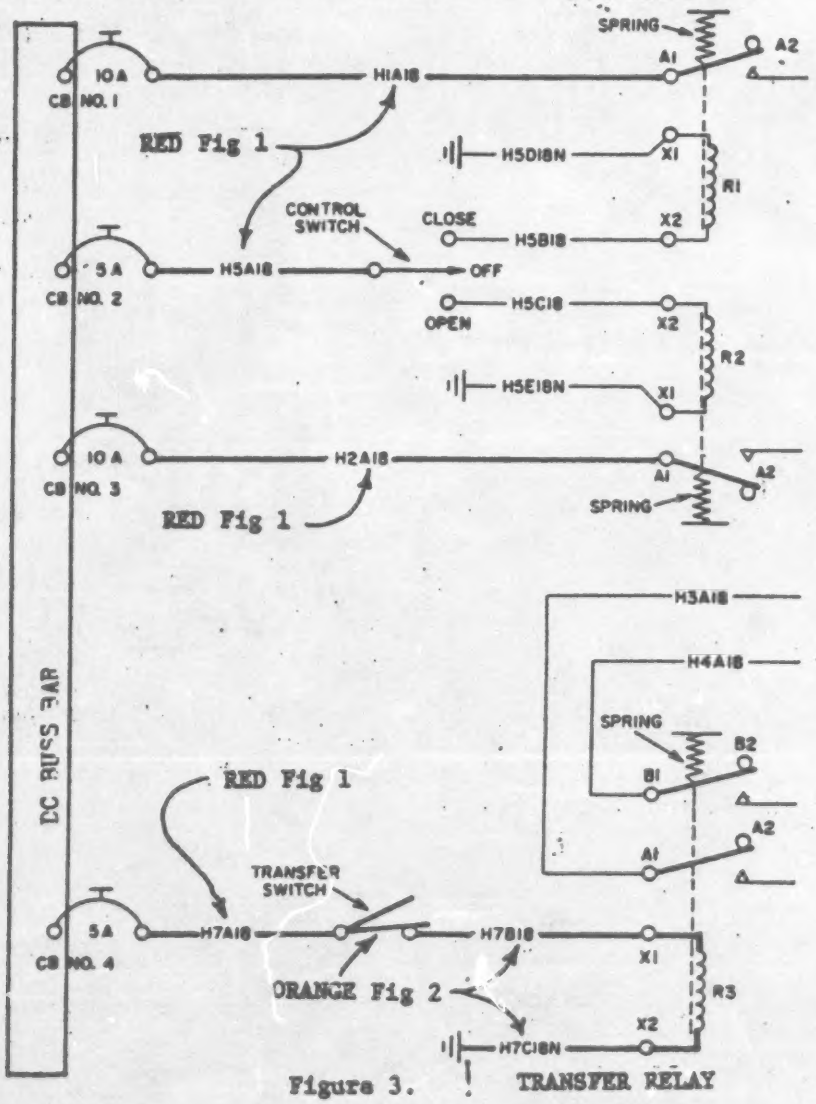
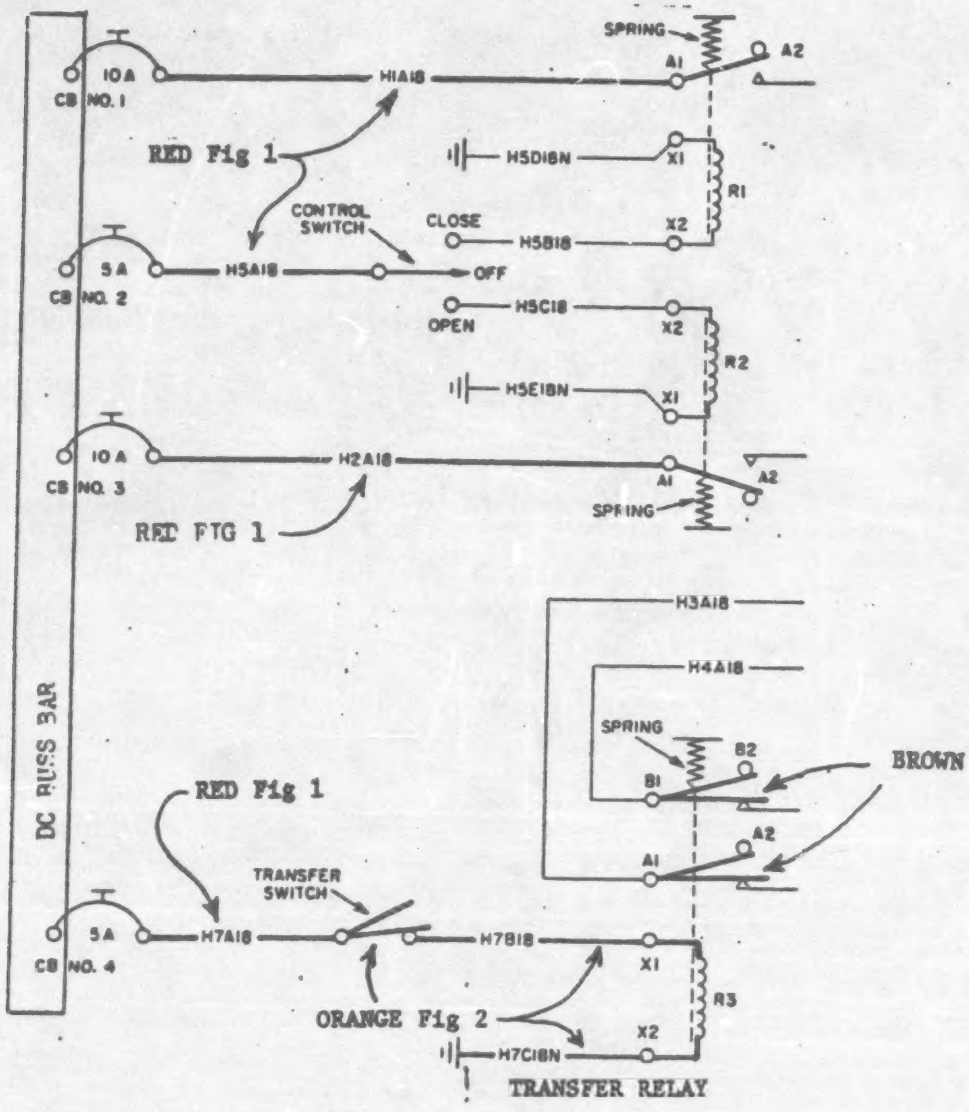


Figure 3.

After tracing the above diagram, turn the page and compare the diagram that you have traced with the diagram on the following page.

Confirmation for Exercise 3:

The bold lines (BROWN) in the diagram below indicate the circuit that you should have traced.



If your diagram was correct, continue the exercises. If not, see your instructor.

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Exercise 4

1. Using a BLUE pencil, trace motor #1 "Close" circuit. At this point you must draw the control switch to the "lose" position.

a. Start the trace from the pole (off) position of the control switch to the close position. Trace from the close position of the control switch along wire number H5B18 to X2 of relay #1. Trace through the coil to point X1, from X1 along wire H5D18N to the common ground point.

(1) You now have a 28V DC potential applied to the relay 1, and a ground for it. From your previous study of relays, you know that the relay will energize (as long as the circuit is good) becoming a temporary magnet and will pull the armature contact down toward the coil making contact from A1 to A2. This completes the voltage circuit from circuit breaker #1 to the "Close" side of the motor.

b. Using a BLUE pencil, draw the contact of relay R1 to the "down" position.

(1) As soon as the electrical path is made across A1 to A2 the voltage is impressed to pin "B" of the connector plug of motor #1.

c. Again using the BLUE pencil, trace from A2 of R1 over wire H1B18 to B of the motor #1, through the limit switch contacts on the motor and down through the "Close" armature winding of the motor to pin "E" over wire H6A18N to the common ground point.

(1) With power applied to the "Close" winding in the motor and a good ground wire the motor's armature would now rotate and turn both a cam (see figure 4) and a valve.

(2) When the cam lobe rotates and presses the plunger in the close limit switch to the arrow contact, it will shut off power to the close winding.

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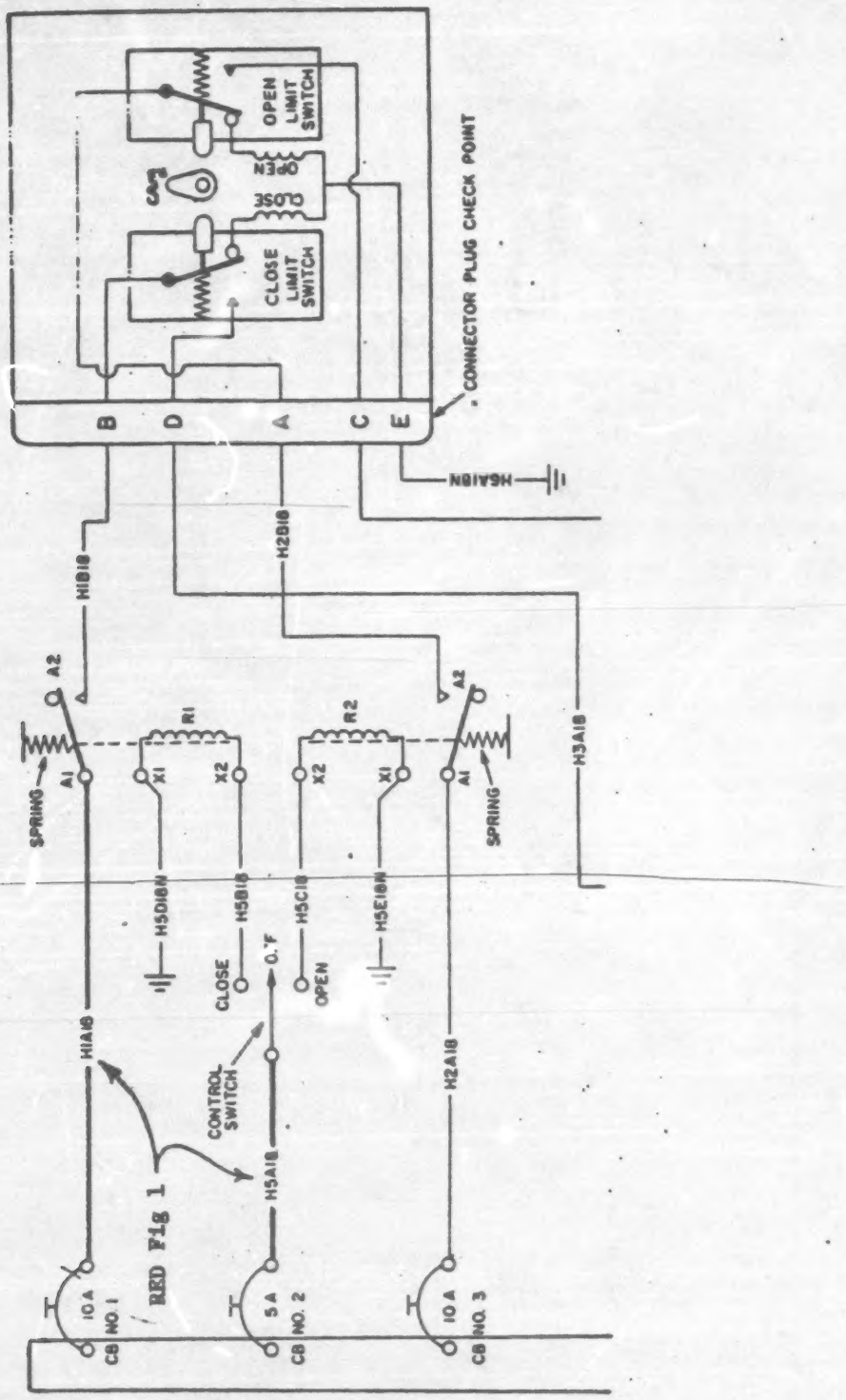
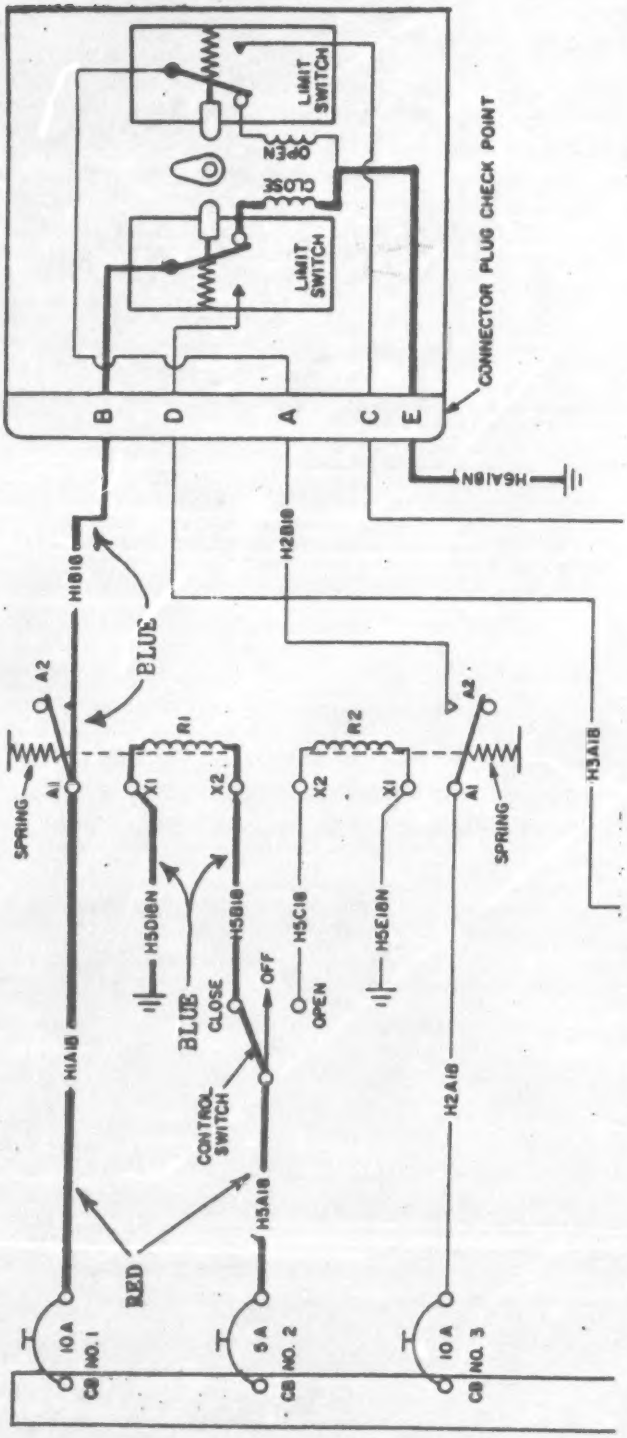


Figure 4.

After tracing the above diagram, turn the page and compare the diagram that you have traced with the diagram on the following page.

Confirmation for Exercise 4:

The bold lines in the diagram below indicate the circuit that you should have traced.



Note: The RED line is a carryover from exercise 1.

If your diagram was correct, continue the exercises. If not, see your instructor.

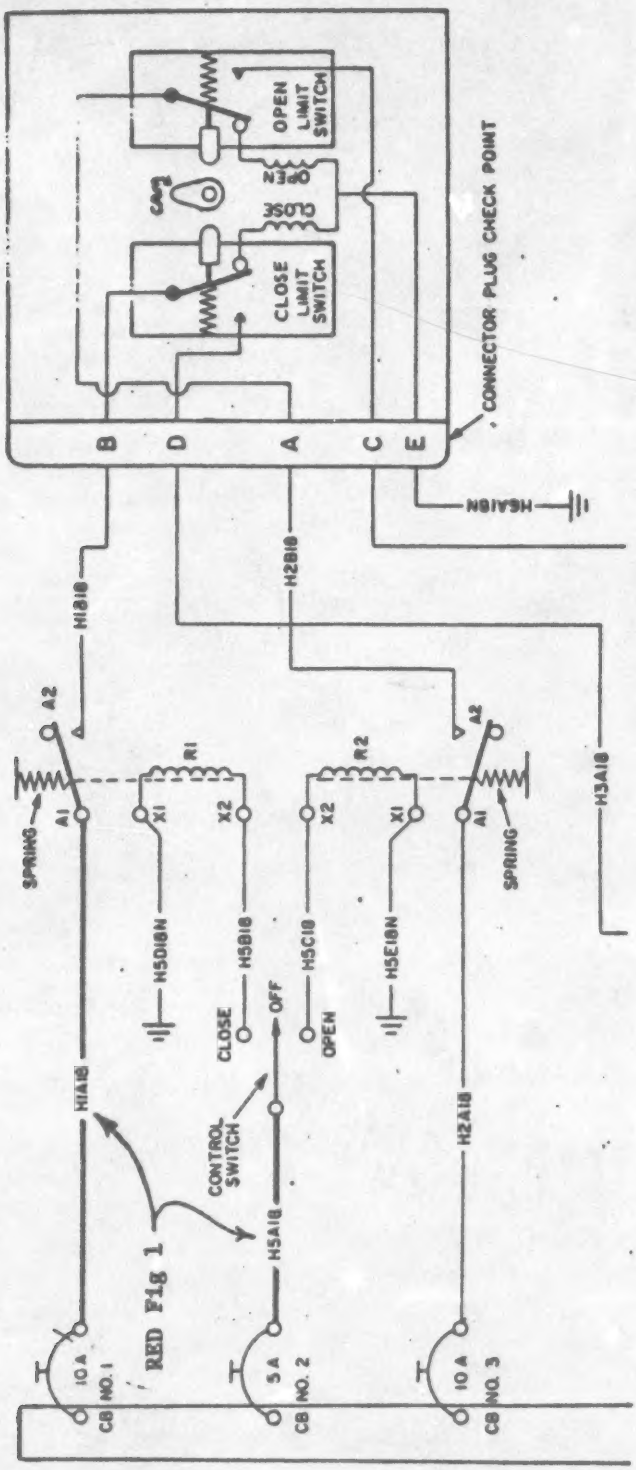
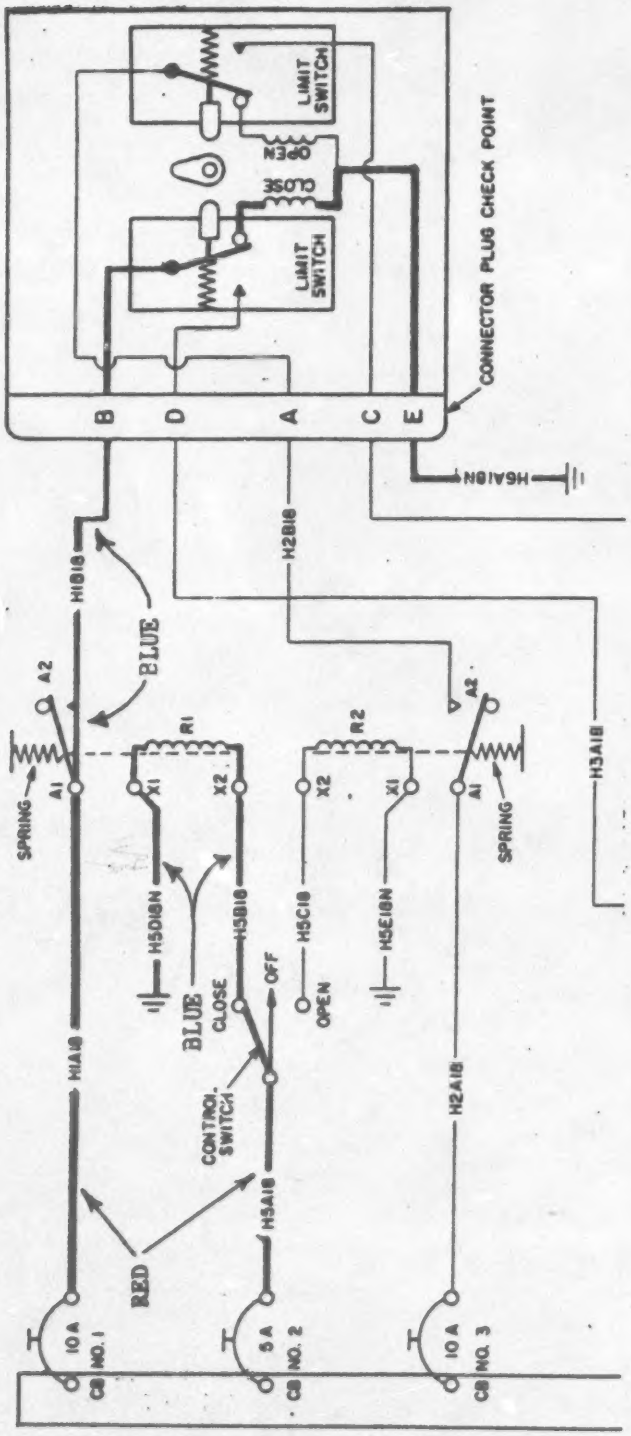


Figure 4.

After tracing the above diagram, turn the page and compare the diagram that you have traced with the diagram on the following page.

Confirmation for Exercise 4:

The bold lines in the diagram below indicate the circuit that you should have traced.



Note: The RED line is a carryover from exercise 1.

If your diagram was correct, continue the exercises. If not, see your instructor.

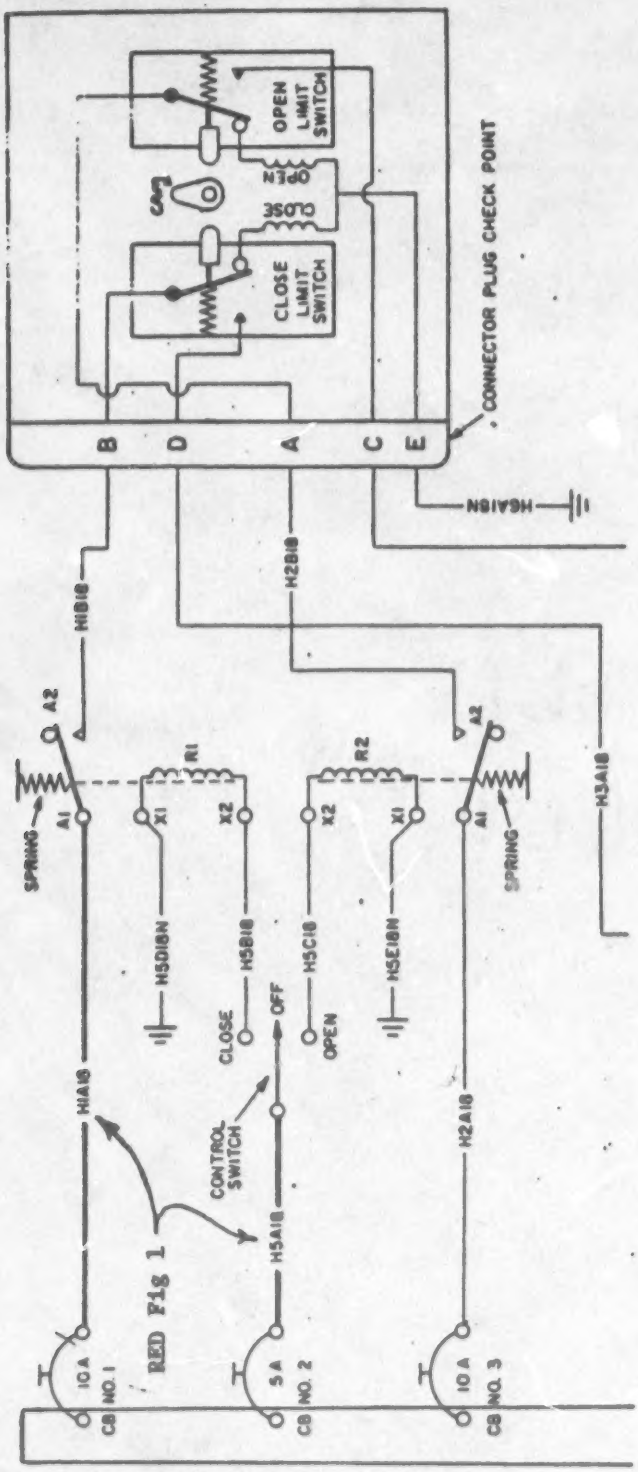
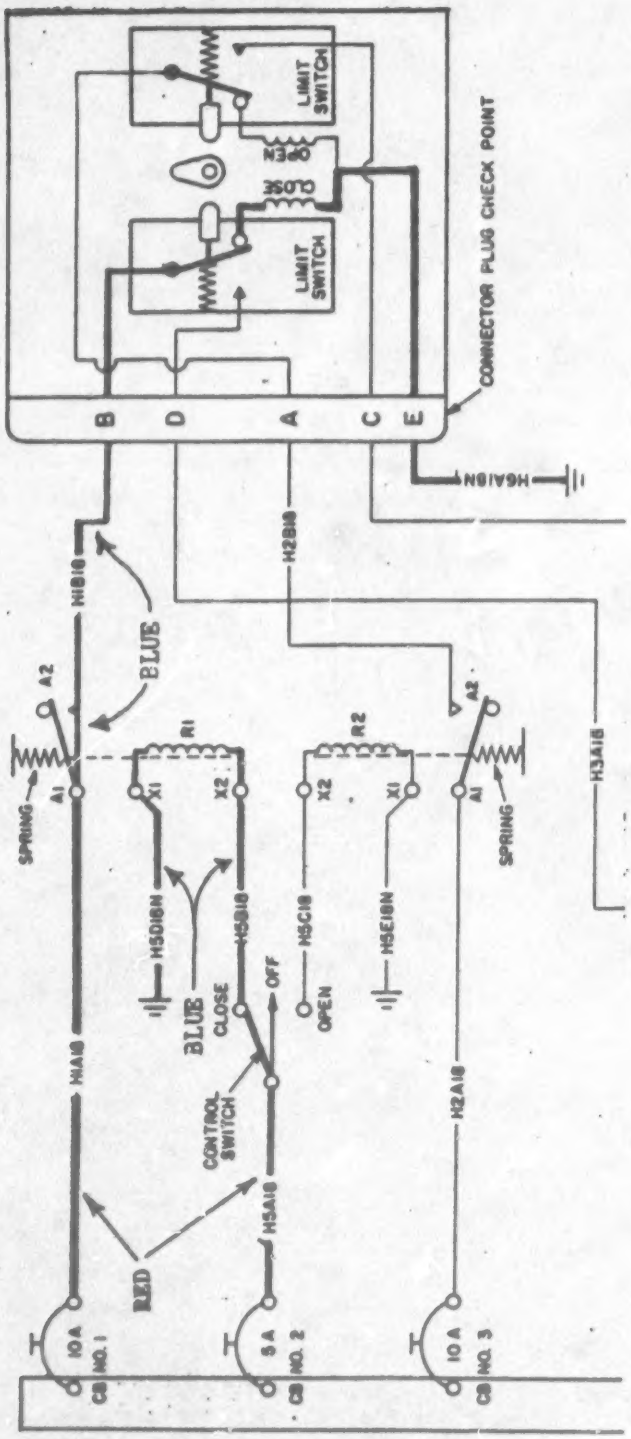


Figure 4.

After tracing the above diagram, turn the page and compare the diagram that you have traced with the diagram on the following page.

Confirmation for Exercise 4:

The bold lines in the diagram below indicate the circuit that you should have traced.



Note: The RED line is a carryover from exercise 1.

If your diagram was correct, continue the exercises. If not, see your instructor.

Exercise 5

Turn to figure 5 and familiarize yourself thoroughly with the basic parts of the DC motor valve assembly. This sketch shows only the parts that concern us. Locate and identify each labeled part by number.

Although this is a simple assembly, let's see how it works. As the motor armature #1 rotates it will then turn the drive gears #2. As the drive gears rotate, they in turn rotate the valve shaft #3. At this point the valve shaft does two jobs. First, it turns the valve butterfly #4 either to the open or closed position. Second, it turns the limit switch actuating cam lobe #5. Examine the cam lobe carefully and note what it looks like and where it is located; further note that the cam lobe is a physical part of the valve shaft.

Figure 5 has a TOP view of the rotating shaft and the limit switch actuation by cam lobe. Study the figure closely.

If you look on either side of the cam lobe you will see two rectangular boxes. These are the "limit switches." One is called the "open" limit switch and the other is called the "close" limit switch.

NOTE THAT THE CAM LOBE IS PERFECTLY CENTERED BETWEEN THE OPEN AND CLOSE LIMIT SWITCHES.

We will discuss the limit switches in more depth later, first complete the following. Turn to figure 5A and label the parts of the DC motor assembly. If you encounter any difficulty in labeling the parts refer back to figure 5 and become more familiar with them. When you complete labeling, refer to figure 5 to check your answers. When you successfully completed this task, go on to exercise 6.

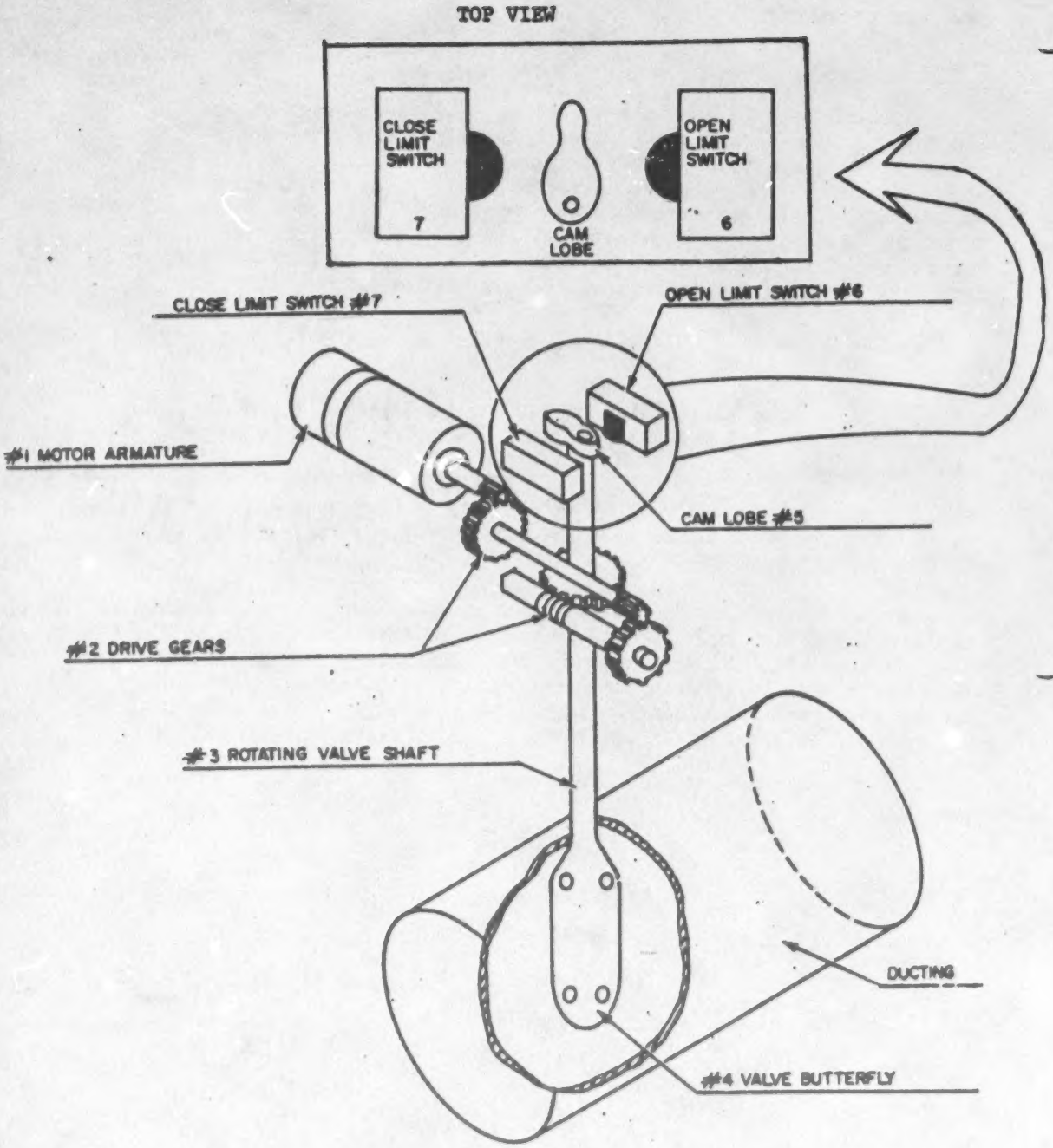

TOP VIEW
CLOSE LIMIT SWITCH
7
CAM LOBE
OPEN LIMIT SWITCH
6
CLOSE LIMIT SWITCH #7
OPEN LIMIT SWITCH #6
#1 MOTOR ARMATURE
CAM LOBE #5
#2 DRIVE GEARS
#3 ROTATING VALVE SHAFT
DUCTING
#4 VALVE BUTTERFLY

Figure 5.

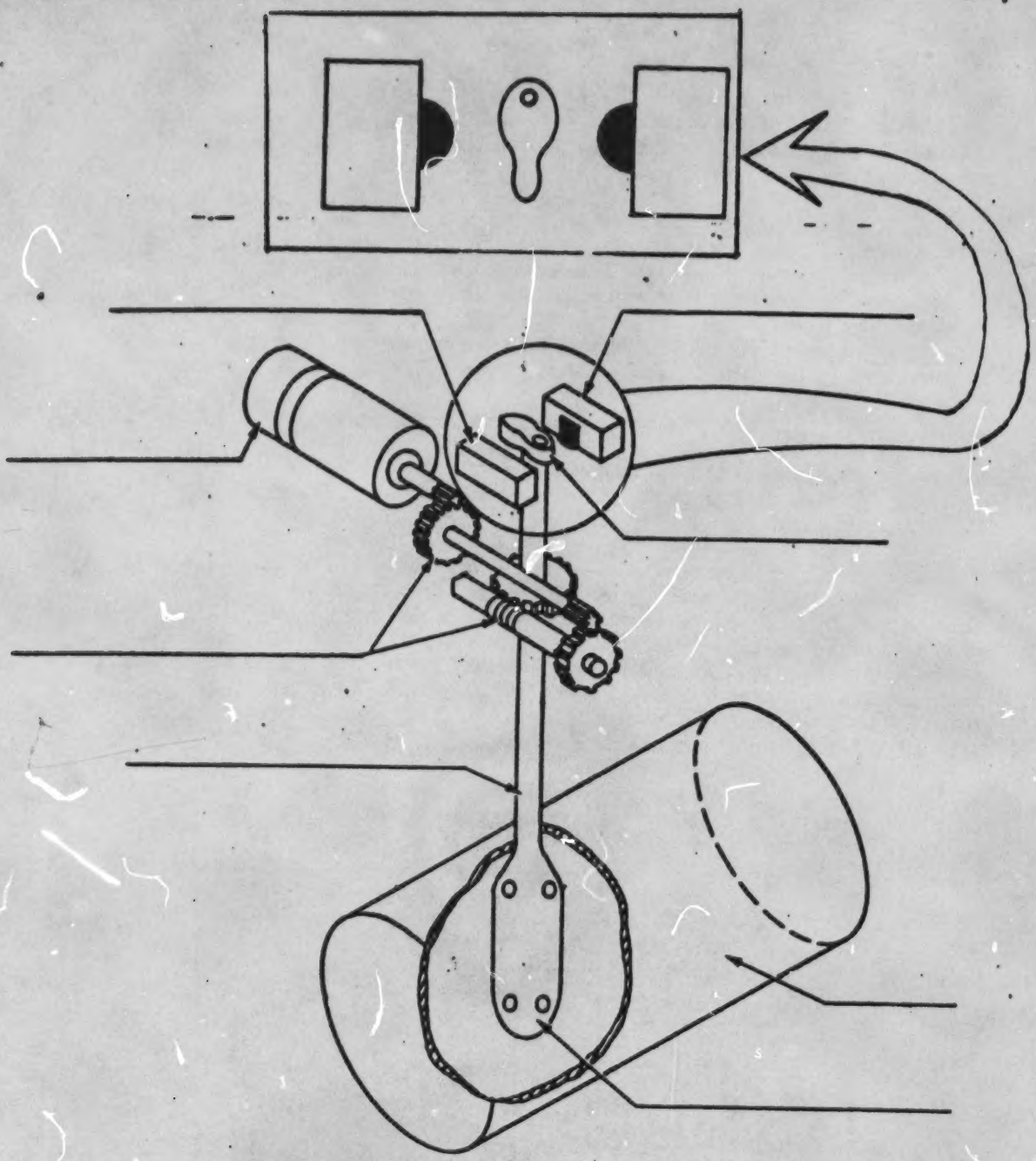


Figure 5a.

After completing the above, turn to figure 5 and compare your work. If your work is correct, continue with the exercises.

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Exercise 6

1. As you recall from the preceding projects, we discussed the location of the limit switches in conjunction with the DC motor valve assembly. Now you will learn exactly what a limit switch is, how it works, and why it is used.

a. A limit switch is a device which is used to limit or stop something from running. An example would be an electrical motor. When a valve assembly goes to full travel (either full open or full closed) you do not want the motor to continue to run. Simply stated we could say a motor is like a "door." Once it is closed it's closed, once it is open it's opened, so why waste more energy trying to close or open something when it has already traveled to its full position.

b. A limit switch is used to stop the valve assembly from trying to go past the fully "closed or opened" position. The limit switch accomplishes this by removing power from either of the armature windings. If we did not stop motor travel the motor would overwork and probably burn up.

2. Refer to figure 6 and locate wire H1B18. If we were to send a 28V DC potential to point B of the motor, power would be impressed across the "Close" armature winding of the motor to ground. Remember, when the armature is energized, the armature will start rotating the valve shaft, turning the cam lobe. As the "cam" lobe leaves the neutral position (by the arrow) note that it is turning toward the close limit switch. Dotted lines indicate the previous position of the cam lobe. Only the wiring that is necessary for this explanation is shown.

a. Refer to figure 6a and notice what happens to the cam lobe and limit switch after the motor has traveled full closed.

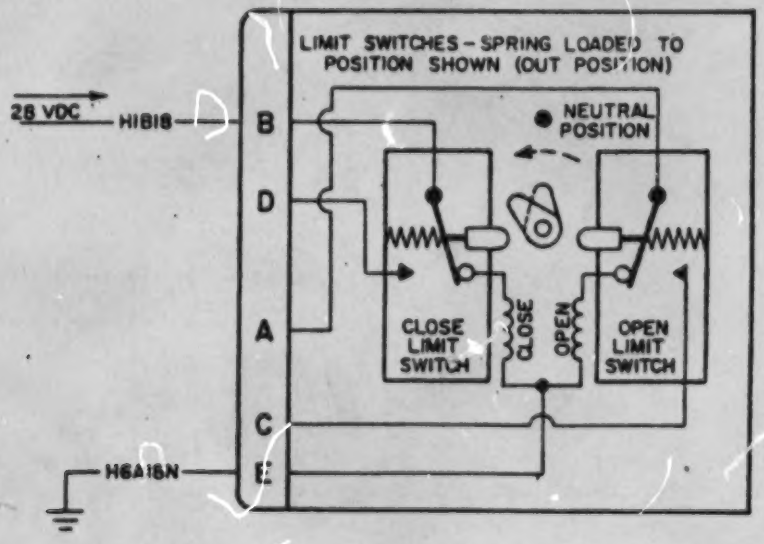

Figure 6.

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b. As the valve assembly finally closes, notice that the cam lobe has rotated around and has depressed (pushed in) the closed limit switch button. If you study figure 6a very closely, you will notice that the cam lobe has depressed the limit switch spring and contact. By this action the voltage is removed from the "close" armature winding. As was stated previously one of the purposes of a limit switch is to stop a valve from opening or closing too far. We do this simply by removing the power from the motor.

(1) Also note that with the close limit switch button depressed the 28V DC power has been re-routed to pin D and then along wire #H3A18; this wire indicates that it goes to another motor (motor #2). There is nothing to say that we can't use the 28V DC for other systems after it does its primary job. <u>But remember, if the primary system does not operate, there is no way that power can be re-routed</u>.

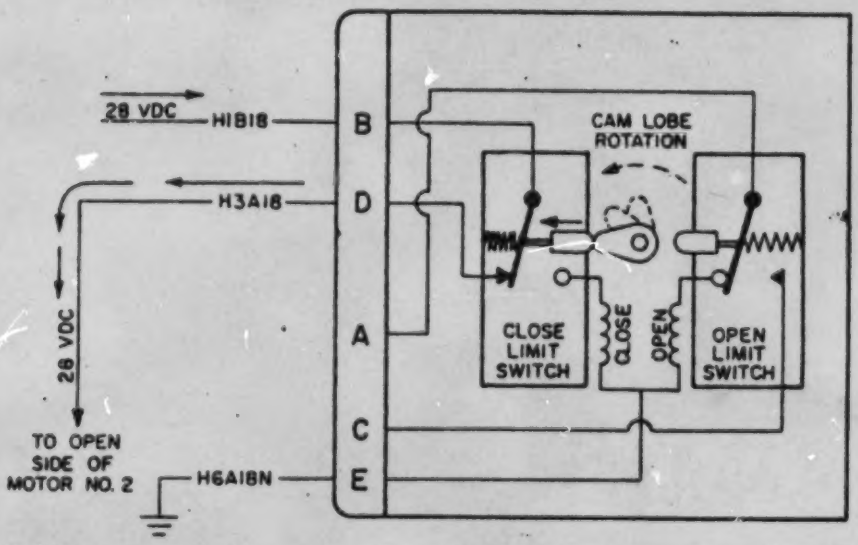

Figure 6a.

c. Now you know why the closed limit switch is used; it is to prevent our DC motor assembly from running too far closed. Its secondary purpose is to control another motor circuit.

d. Now let's see what will happen if you apply voltage to the "open" side of the circuit. We will start from the full close position and go to the full open. Refer to figure 6b.

(1) <u>Assume</u> now that you energize a circuit and send power in on wire number H2B18 to pin A of the motor, through the open armature winding to the ground. As the armature starts to rotate toward open, the valve shaft and cam lobe start turning (dotted lines & direction of arrow).

(2) Note that as the cam lobe is turned the "Close" limit switch button is released. Remember, these switches are spring loaded.

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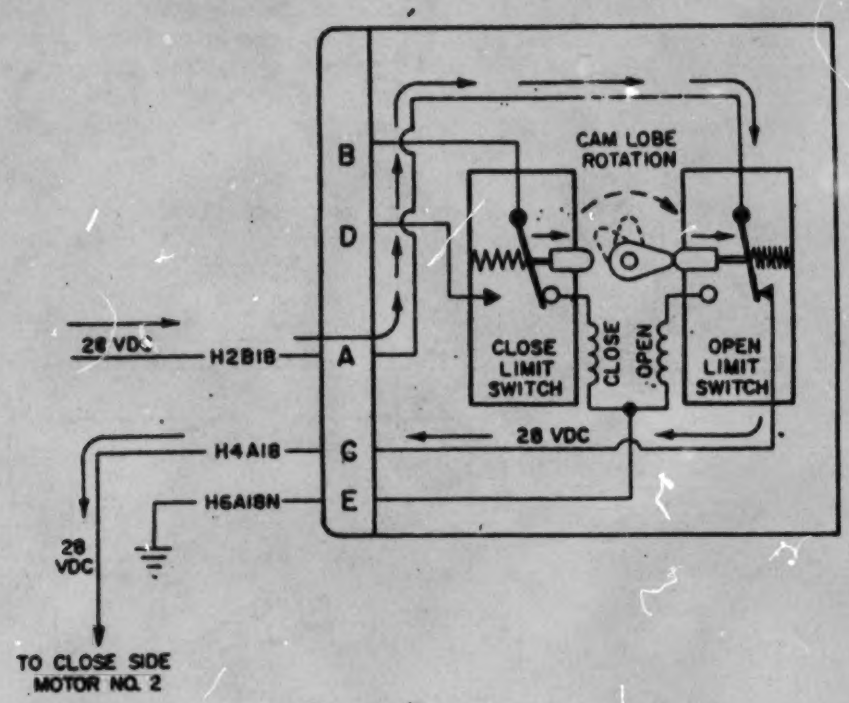

Figure 6b.

(a) This action sets the "close side" up for operation again.

(3) As the cam lobe reaches full travel (shown by solid cam lobe) the limit switch button has been depressed and as a result:

(a) power is removed from the open armature winding.

(b) power is re-routed along wire number H4A18 to the close side of motor #2.

e. To better understand limit switch operation refer to the electrical display box #8 (located in the classroom). Locate the microswitch cam. Physically turn the round black knob (this normally would be armature rotating) and actuate the limit switches. Observe the action.

3. With your knowledge of how a limit switch operates and why it is used, continue with your color tracing in exercise 7.

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Note: you have already applied power to motor valve #1 on the close side in figure 4. Let us now say that the valve is fully closed and the LIMIT switch is depressed.

1. Using a BLUE pencil, trace motor valve #2 OPEN circuit.

a. Draw the CLOSE LIMIT switch in the depressed position in figure 7 then trace from the LIMIT switch contact to point "D" of the motor.

b. Next trace from point "D" of motor valve #1 along wire H3A18 to A1 of relay R3.

(1) Back in exercise 3 you have already energized relay #3, so the contacts of the relay are down and ready to transfer voltage across A1 to A2 and on to motor valve #2.

c. Trace across the contacts of relay R3 from A1 to A2.

d. Trace from A2 along wire H3B18 to point "A" of motor valve #2 connector plug.

e. Now trace from "A" of the connector plug of motor valve #2 through the LIMIT switch contacts, on through the OPEN FIELD winding of the motor. Trace from the field winding to point "E" of the connector plug. From point "E" along wire H6B18N to the common ground.

(1) Stop a minute and examine what you have done thus far in the text.

(a) You have applied power to your circuits. You put the power to work by closing motor valve #1. If you examine your circuit you will note that by closing motor valve #1 you OPENED motor valve #2 through the use of the LIMIT switch if the TRANSFER switch is CLOSED.

Note: Confirmation page for exercise 7 is identified with "BLUE FIG 7" and an arrow pointing to the heavy bold line. The other heavy bold lines are identified by their color and the figure on which you have traced the circuit. You may refer back to these figures as needed.

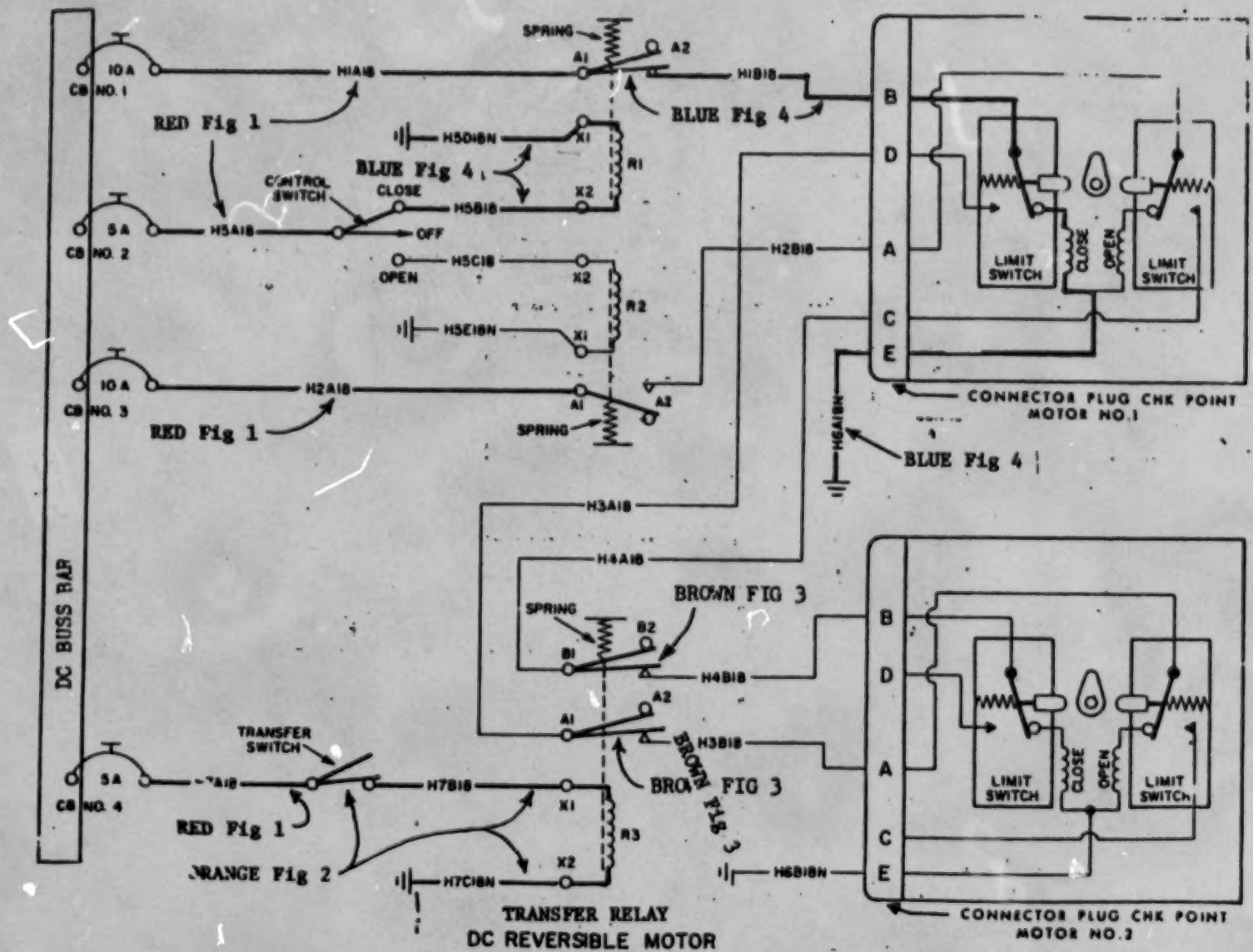
DC BUSS BAR
CB NO. 1
10 A
H1A1B
SPRING
A1
A2
H1B1B
RED Fig 1
BLUE Fig 4
H5D1BN
X1
R1
BLUE Fig 4
CONTROL SWITCH
CLOSE
H5B1B
X2
CB NO. 2
5 A
H5A1B
OFF
OPEN
H5C1B
X2
R2
H5E1BN
X1
CB NO. 3
10 A
H2A1B
RED Fig 1
A1
A2
SPRING
H2B1B
H3A1B
H4A1B
BROWN FIG 3
SPRING
B1
B2
H4B1B
A2
A1
TRANSFER SWITCH
CB NO. 4
5 A
H7A1B
H7B1B
X1
R3
RED Fig 1
ORANGE Fig 2
H7C1BN
X2
H3B1B
BROWN FIG 3
H6B1BN
H6A1BN
BLUE Fig 4
B
D
A
C
E
LIMIT SWITCH
CLOSE
OPEN
LIMIT SWITCH
CONNECTOR PLUG CHK POINT MOTOR NO.1
CONNECTOR PLUG CHK POINT MOTOR NO.2
TRANSFER RELAY
DC REVERSIBLE MOTOR

Figure 7.

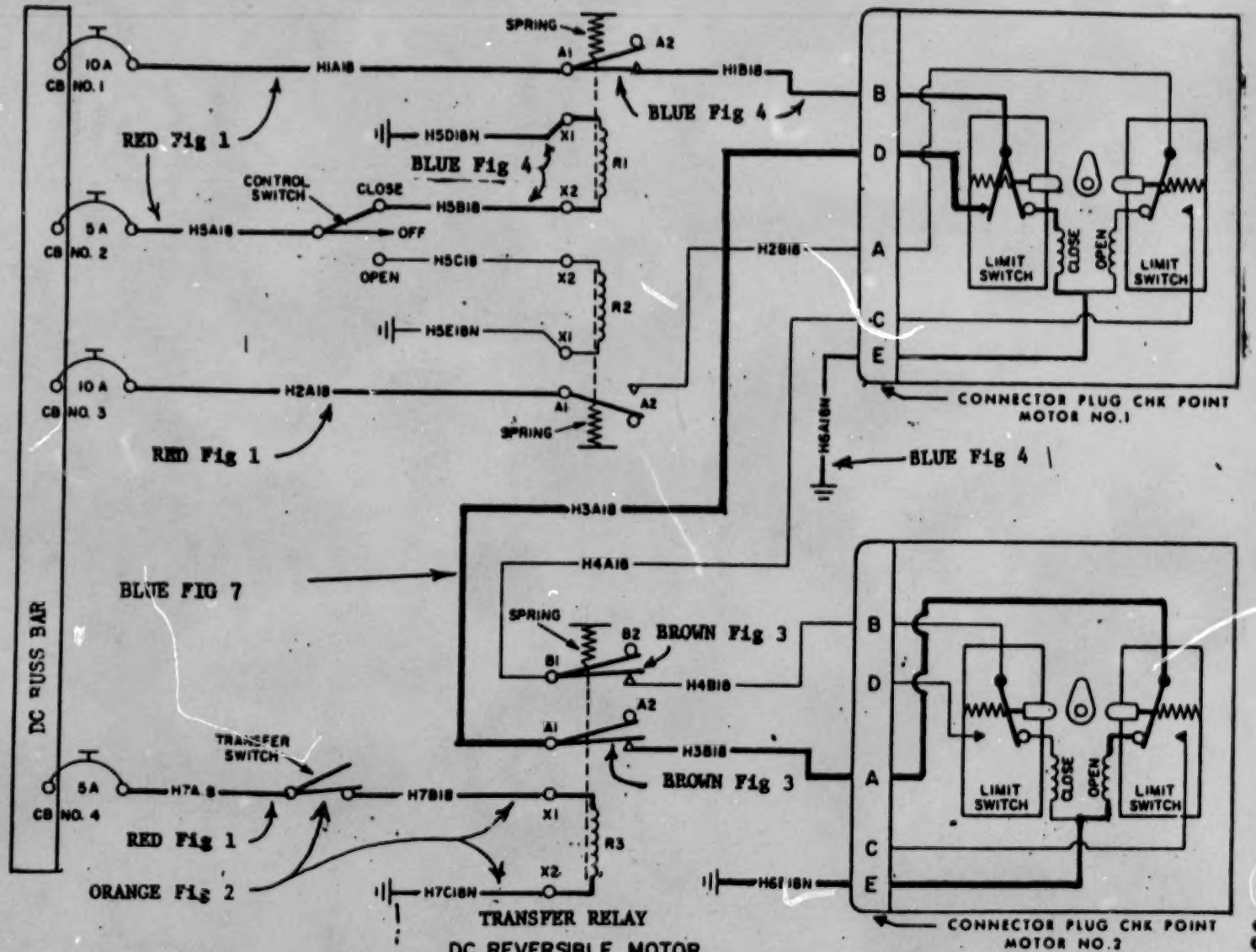

Figure 7a.

If your diagram was correct, continue the exercise. If not, see your instructor.

Confirmation for Exercise 7:

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Exercise 8

1. Using a GREEN pencil, trace motor #1 "open" circuit.

a. Trace from the pole "OFF" position of the control switch to the "OPEN" position of the control switch.

b. Trace from the open position of the control switch along wire #H5C18 to X2 of relay #2, through the coil to point X1. Trace from X1 along wire H5E18N to the common ground point.

c. Using the green pencil, draw the contact of relay #2 to the "UP" position (A1 to A2).

(1) As soon as the electrical path is made across A1 to A2, the voltage potential that was up to A1 is impressed across the path from A1 to A2 then to the motor.

d. Trace from point A2 along wire H2B18 to A of the connector plug of motor #1, then through the limit switch contacts and on through the open field winding of the motor to point E.

e. Trace from point E along wire H6A18N to the common ground.

(1) With power applied to the open winding and a good ground, the motor armature would begin to rotate and open the valve.

Note: Before continuing with the rest of the tracing, refer back to exercise 6 describing the operation of the open limit switch, then continue with this exercise.

f. There are a few items that you should note about the combined operation of the two motors. They are:

(1) The top motor (motor #1) controls the bottom motor (motor #2) through the open or close limit switches.

(2) If for <u>any</u> reason motor #1 does not operate (run), there is no way that motor #2 can operate.

(3) The two motors operate opposite of each other; when motor valve #1 runs to the open position, motor valve #2 runs to the close position.

(4) When motor #1 runs to the close position motor #2 runs to the open position.

(5) Motor #2 DOES NOT control motor #1. If only motor valve #2 fails to OPEN and/or CLOSE, it will not affect motor valve #1.

Note: If there is any doubt in your mind pertaining to the motor operation at this point, go back over ALL the preceding exercises.

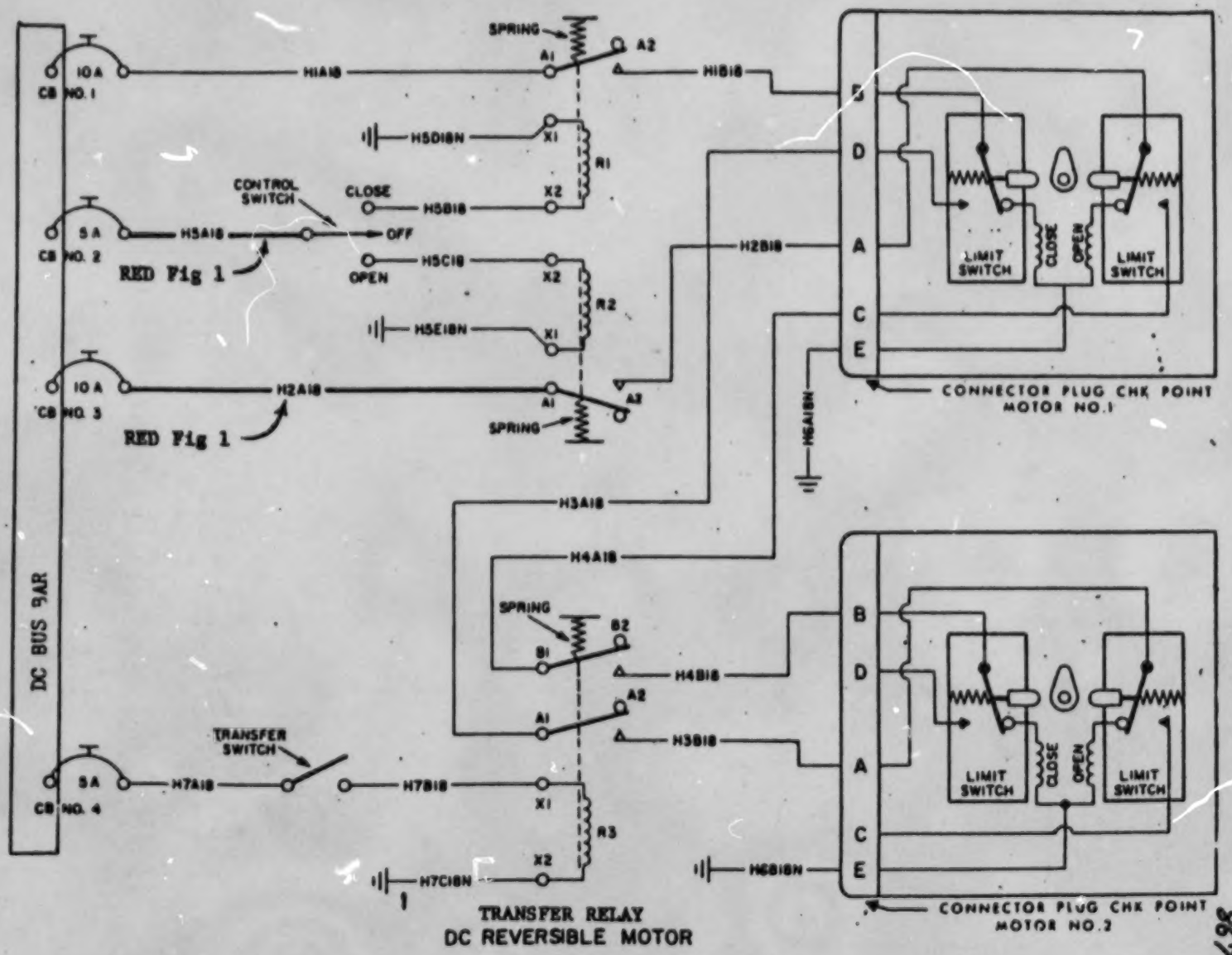

Figure 8.

After tracing the above diagram, turn the page and compare the diagram that you have traced with the diagram on the following page.

23

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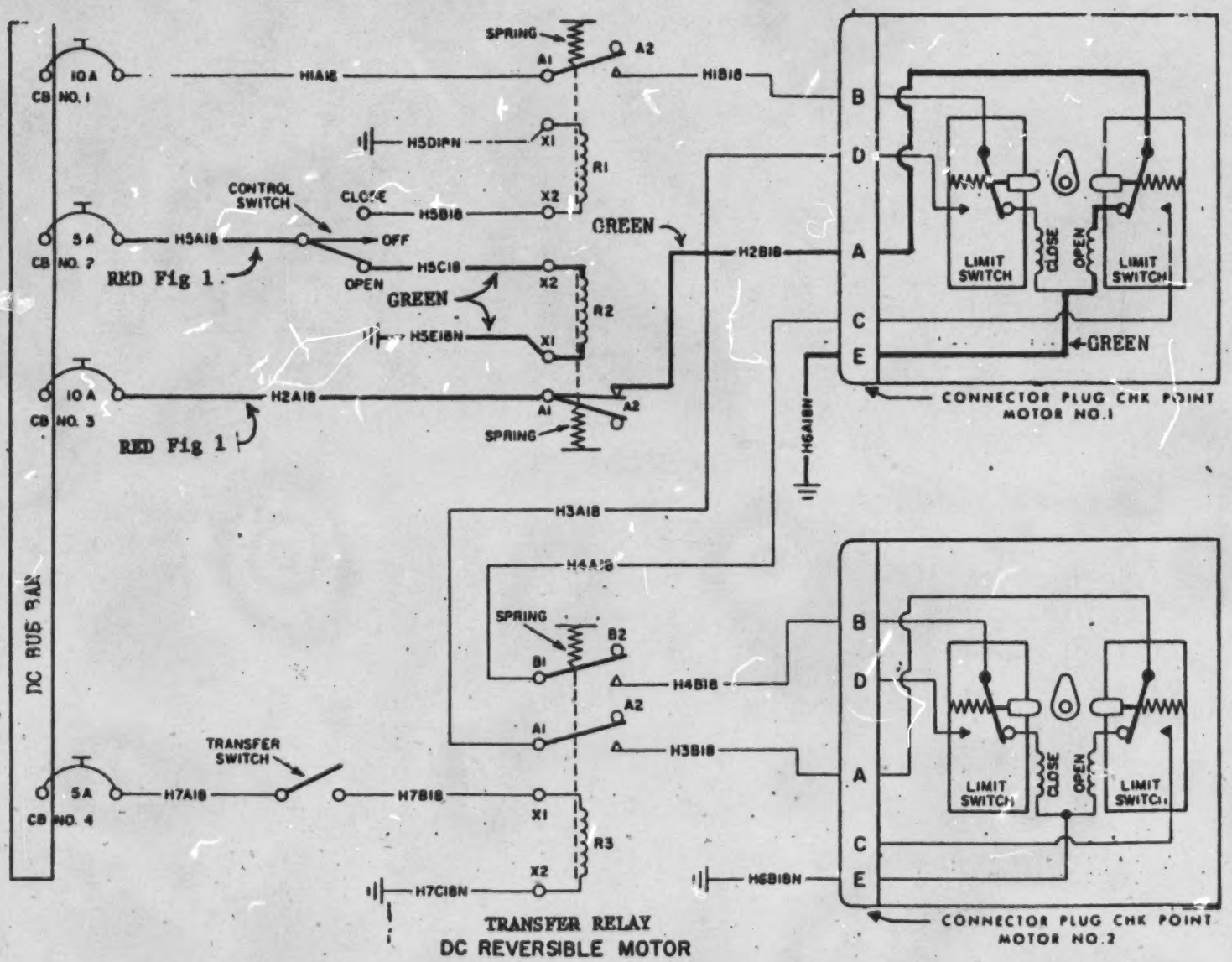

If your diagram was correct, continue the exercises. If not, see your instructor.

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Confirmation for Exercise 8:

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Note: You have already applied power to motor #1 on the OPEN side on figure 8. Let's now say that the motor is finally open and the limit switch has been depressed.

1. Using a GREEN pencil, trace motor #2 "Close" circuit.

a. Draw the depressed OPEN limit switch from the limit switch to point C of the connector plug on motor valve #1.

b. Trace from point C of motor #1 along wire #H4A18 to point B1 of relay #3. In exercise 3 you have already energized relay #3, so the contacts of the relay are down, and ready to transfer the voltage to motor #2.

c. Trace across the contacts of relay #3 from B1 to B2.

d. Trace from B2 along wire #H4B18 to point B of motor #2.

e. Now trace from point B of the connector plug of motor #2 through the limit switch contacts through the close field winding of the motor at point E.

f. Trace from point E of the motor along wire H6B18N to the common ground point. Again let's see what you have done. You have turned the control switch to the OPEN position. In turn you OPENED motor #1 and CLOSED motor #2.

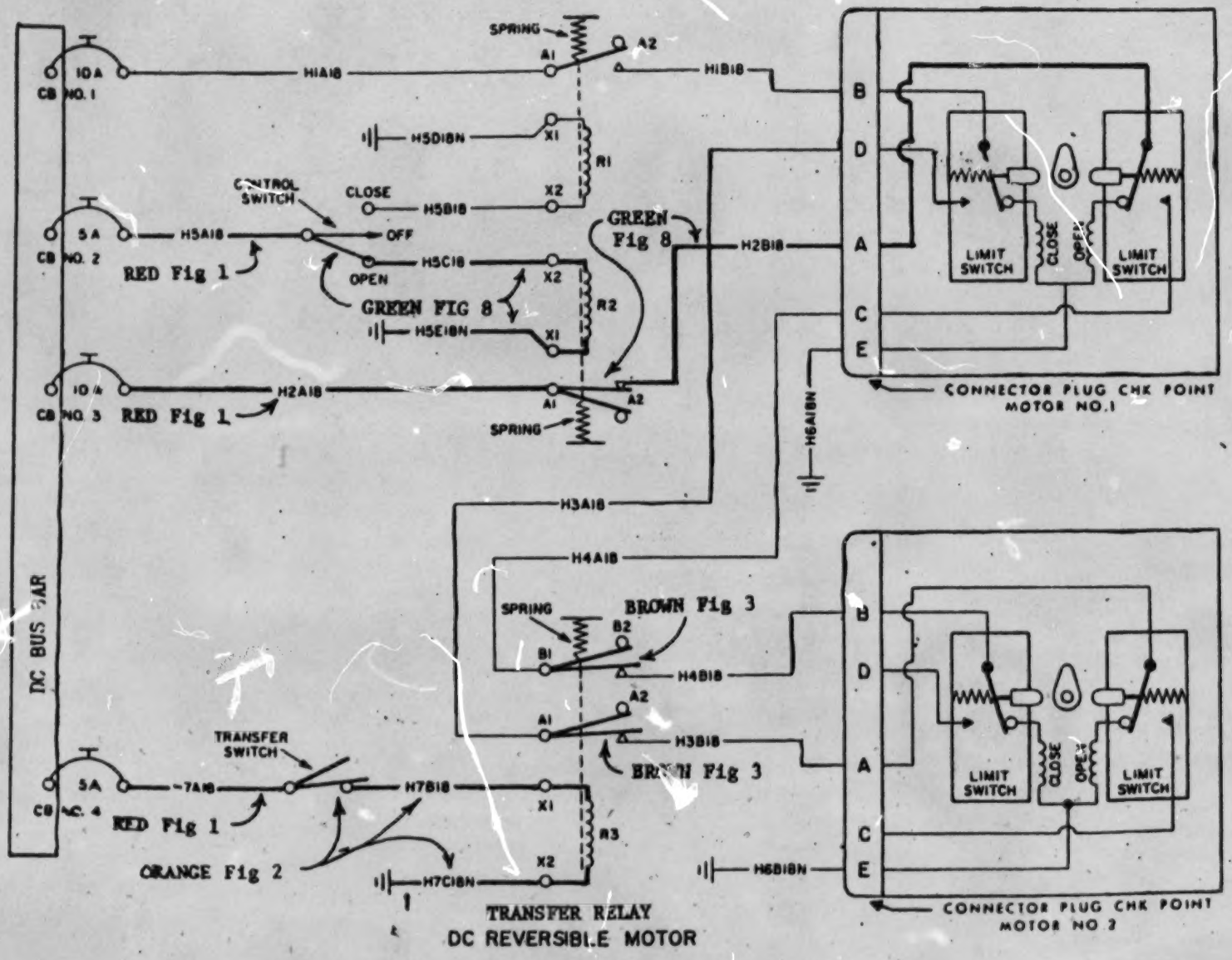
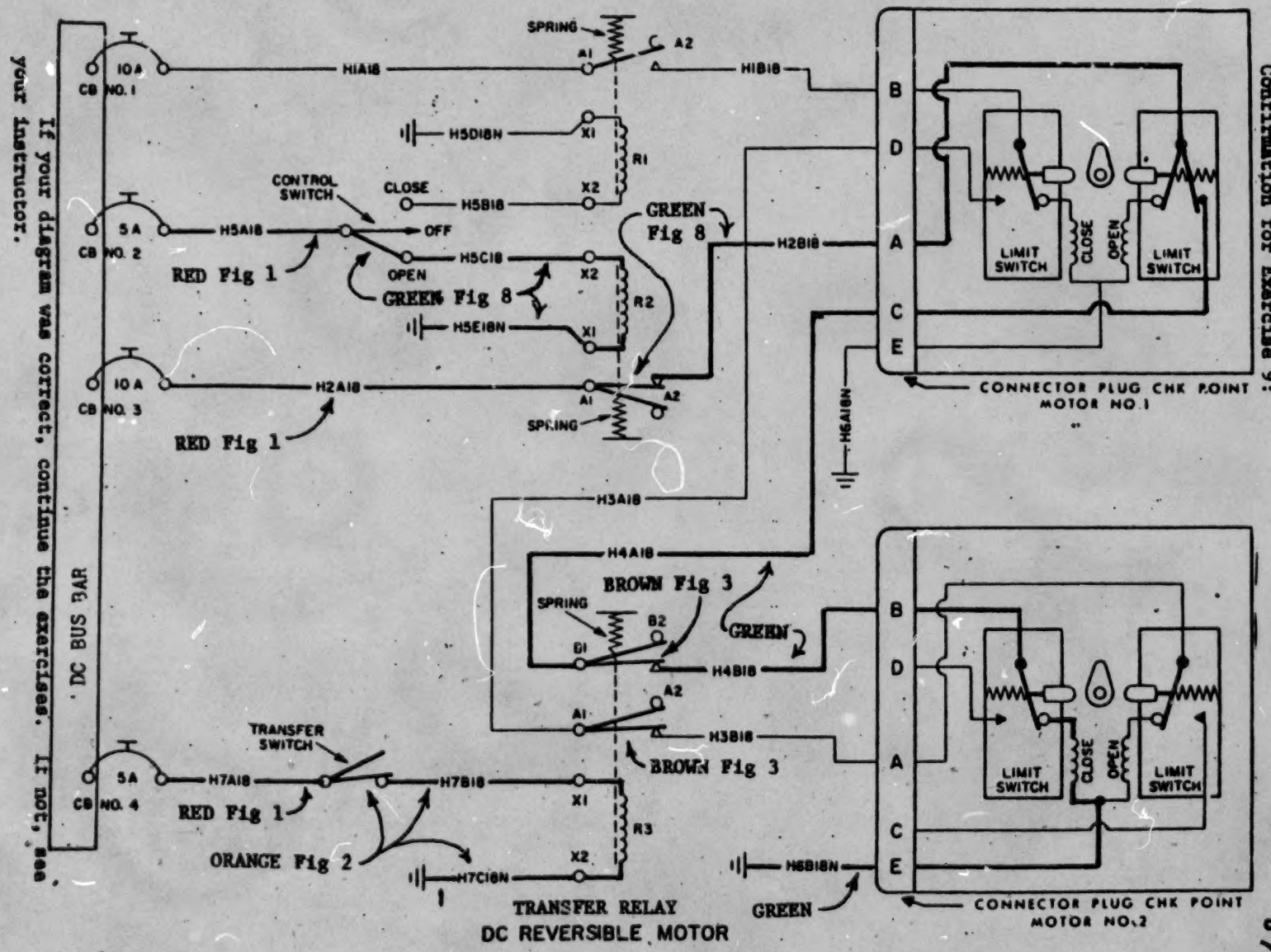


Figure 9.

After tracing the above diagram, turn the page and compare the diagram that you have traced with the diagram on the following page.

26



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Using figure 10 and figure 11, you will identify the circuit malfunction(s) in the DC motor control circuit which are all caused by open circuit(s). You will place an "X" in the block which will give you the correct circuit malfunction. The first one (1) has been done for you. The second one you must do for practice and have it checked by your instructor before you progress to the problems in the progress check.

PRACTICE PROBLEM 1

First look at figure 11 and find practice problem 1 and then, using figure 10, look for problem #1 in the DC reversible motor control circuit. After you have found #1 on figure 10, you will see that it points to an open ground for motor valve #1. Remember that all the problems given in this exercise are open circuits.

1. Figure 11 gives you the answer sheet for practice problem #1.

2. Figure 10 gives you the location of the open circuit H6A18N ground for motor valve #1.

Note: An "OPEN CIRCUIT" may be a condition of an electrical circuit caused by the breaking of continuity of one or more of the conductors of the circuit; usually an undesired condition. It may also be a circuit which does not provide a complete path for current to flow.

3. The left column of figure 11 gives the circuit condition for each open circuit (control switch closed and R3 energized). In problem #1 the open ground circuit will not allow the electrons for flow, thus affecting both the CLOSE and OPEN windings (load) of the motor. You also know from exercise 8 if motor valve #1 fails to operate motor #2 will also fail to operate. With this in mind select the correct circuit malfunction given at the top of figure 11 by placing an "X" in the correct block, which has already been done for you.

The selection made is circuit malfunction (motor valve #1 and #2 inoperative). This is the only complete and correct answer because the motor ground is for both the OPEN and CLOSE windings, this causing motor valve #1 to be completely inoperative. Because motor valve #1 must operate before motor valve #2, motor valve #2 is also inoperative. The above circuit malfunction will result regardless of the control switch position (close or open).

You might have selected circuit malfunction (motor #1 will not close and motor #2 will not open) which is only half (1/2) correct. This states only half of what is wrong with each motor valve. You must remember the motor valve grounds will affect both the open and close operation of its motor.

Note: Be very CAREFUL in selection of the circuit malfunctions. They must describe exactly what is malfunctioning, nothing more or less. Also always note the position of the control and transfer switches given in the circuit condition column in figure 1.

PRACTICE PROBLEM #2

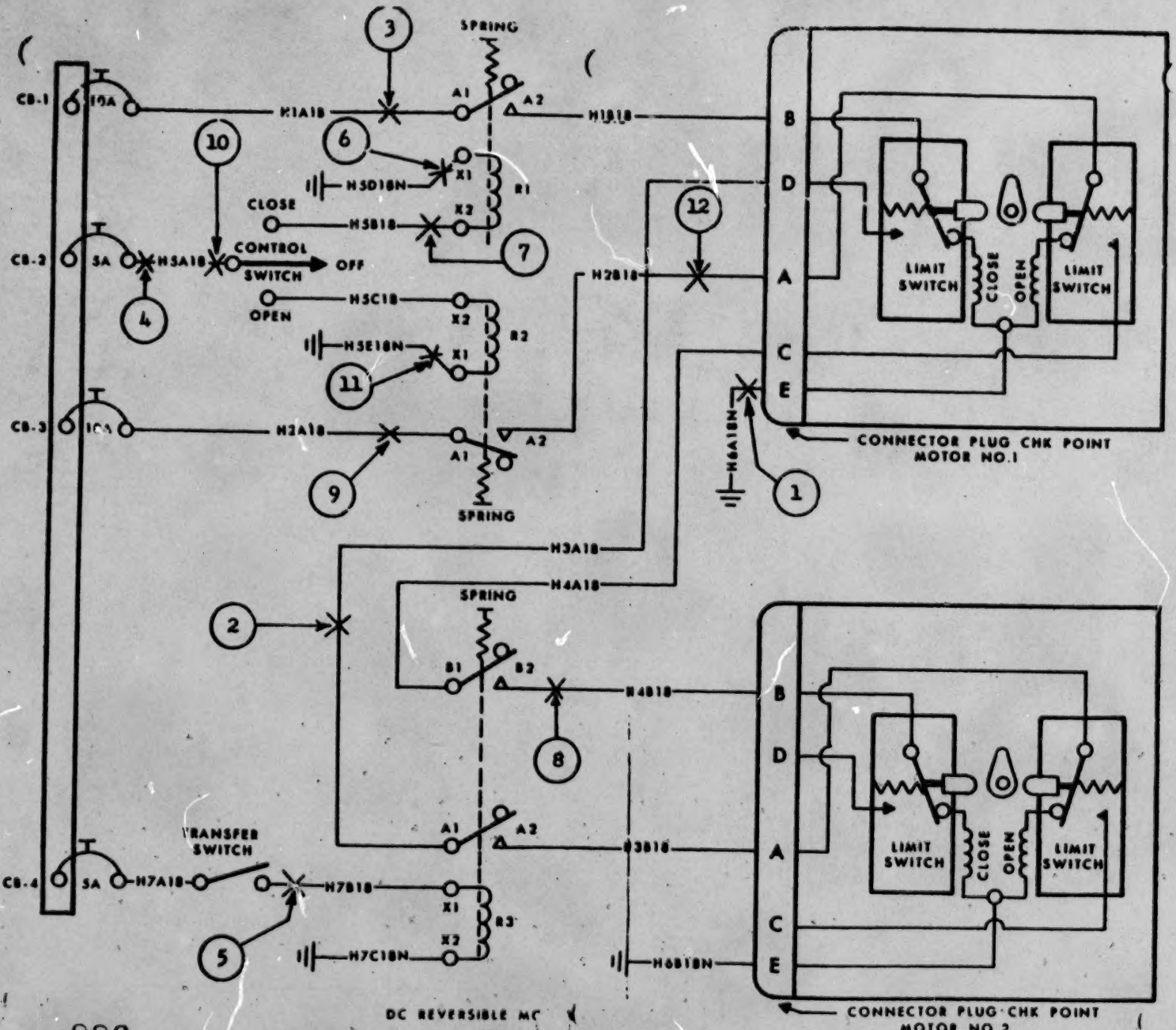
First look at figure 11 and find practice problem 2 and then using figure 10, look for problem #2 in the DC motor control circuit. After you have found #2 on figure 10, you will see that it points to motor 2 open control circuit. Remember all the problems given are open circuits.

1. Figure 11 gives you the answer sheet for practice problem #1.

2. Figure 10 gives you the location of the open circuit H3A18 for motor #2 open circuit.

3. The left column of figure 11 gives the circuit condition for each open circuit (control switch closed and R3 energized). Problem #2 open circuit will not allow the electrons to flow, thus affecting only the open winding in motor 2 with R3 energized. You know from the past exercises that if R3 is energized and motor 1 will close the valve normally that motor 2 is to open its valve. With this in mind, select the correct circuit malfunction given at the top of figure 11 by placing an "X" in the correct block. Your instructor will grade your work and initial it if you are to progress to the next five problems.

The next five problems will not be done any place but in the classroom and under the supervision of the instructor. You will not do these problems in the barracks or at home. You must identify a minimum of 8 out of 10 circuit malfunctions correctly. Your instructor must check your work after the first five problems. If your instructor says your work is satisfactory the instructor will initial your work allowing you to progress. If the instructor says your work is unsatisfactory, it will not be initialed and you will follow the instructions of the instructor.



886

FIG 10

Figure 10.

887

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Student complete the following (print).

STUDENT NAME _____
(last) (first)

DATE PROGRESS CHECK STARTED _____

CIRCUIT CONDITION	CIRCUIT MALFUNCTION: Motor #1 will not CLOSE and motor #2 will not OPEN.	Motor #1 will not OPEN and motor #2 will not CLOSE.	Motor #2 will not CLOSE.	Motor #1 will not CLOSE.	Motor #2 will not OPEN.	Motor #1 will not OPEN.	Motor #1 & #2 inoperative.	Motor #2 inoperative.	Motor #1 inoperative.	Numbers on f (Open circuits) (Problem numbers)	
Control Sw. CLOSED and R3 energized.							X			1	Practice Problems
Control Sw. CLOSED and R3 energized.										2	
INSTRUCTOR MUST INITIAL BEFORE STUDENT IS TO PROGRESS →											
Control Sw. CLOSED and R3 energized.										3	Progress Check 1st half
Control Sw. CLOSED or OPEN and R3 energized.										4	
Control Sw. CLOSED or OPEN and TRANSFER Sw. CLOSED.										5	
Control Sw. CLOSED and R3 deenergized.										6	
Control Sw. CLOSED and R3 energized.										7	
INSTRUCTOR MUST INITIAL BEFORE STUDENT IS TO PROGRESS →											
Control Sw. OPEN and R3 energized.										8	Progress Check 2nd half
Control Sw. OPEN and R3 deenergized.										9	
Control Sw. OPEN or CLOSED and R3 deenergized.										10	
Control Sw. OPEN and R3 energized.										11	
Control Sw. OPEN and R3 deenergized.										12	
INSTRUCTOR MUST INITIAL BEFORE STUDENT IS TO PROGRESS →											

Figure 11.
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WORKBOOK

3ABR42331-WB-121A

Technical Training

Aircraft Environmental Systems Mechanic

DC MOTOR AND CONTROL CIRCUIT TROUBLESHOOTING

5 December 1978

CHANUTE TECHNICAL TRAINING CENTER (ATC)
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Environmental Pneudraulics Branch
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3ABR42331-WB-114A

DC MOTOR AND CONTROL CIRCUIT TROUBLESHOOTING

OBJECTIVE

Using DC motor control circuit, electrical diagrams, and multimeter, locate and record a minimum of 4 of the 5 troubles.

EQUIPMENT

	Basis of Issue
Trainer P/N 18501387, DC Reversible Motor System	1/student
Multimeter	1/student

CAUTION: Remove watches, rings, bracelets, etc., before starting any work on the equipment. It is also a good safety practice to work on the equipment with one hand. This practice reduces the chances of receiving an electrical shock to some vital body organ when working with electricity.

PROCEDURE

The first seven pages will be done without the trainer. They may be done in the lab and/or classroom at the descretion of the instructor(s). Page 8 on will be done in the lab. After you get to the lab ask the lab instructor to assign you a trainer to complete the workbook and progress check. You will also need a multimeter. Follow the procedures that are given in each exercise.

When you leave your trainer for a scheduled or unscheduled break, insure that the following procedures are done before you leave.

1. Place the CONTROL SWITCH to the OFF or center position.

2. Place the TRANSFER SWITCH to the OFF position.

3. Secure your multimeter during this period.

   a. Insure the controls on the meter are properly set for storage.

   b. Leave the test leads attached to the meter.

   c. Wrap the test leads around the meter.

   d. Place the meter on the locker shelf.

4. When you return from your break take the same meter from the locker and go back to work.

Supersedes 3ABR42331-WB-114A, 30 December 1976
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890

1. Before starting with the troubleshooting exercise, thoroughly refamiliarize yourself with the operation of the voltmeter.

a. In order for the multimeter to read voltage (AC or DC) there must be power applied to the circuit to have a voltage potential or a difference between a positive point and a negative point.

(1) To better understand what is meant by this, look at figure 1 below and continue reading.

(2) If the voltmeter leads were placed into the circuit as shown in figure 1, the meter would indicate a "0" (zero) voltage reading. The reason is because the wire between the two leads allows the same voltage (pressure) to exist at both ends of it. Because its the same at both ends, the meter cannot measure a difference.

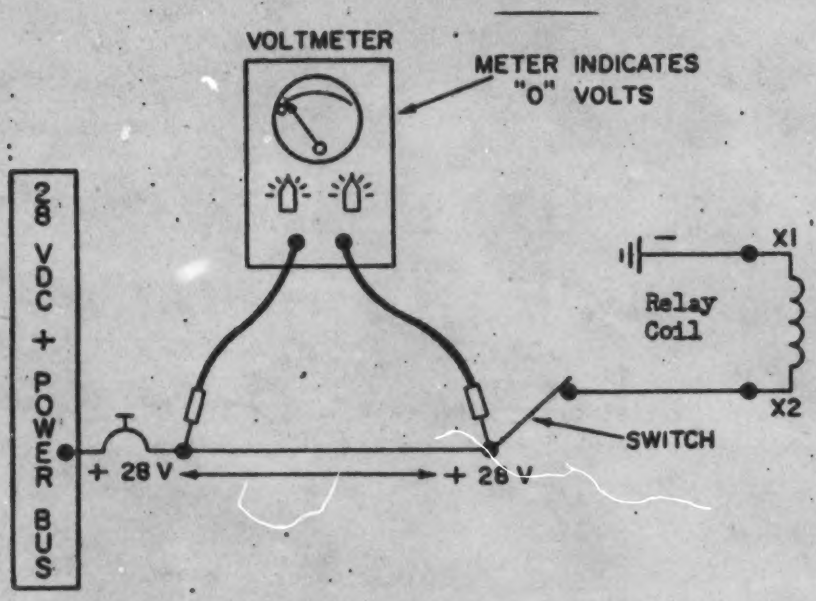

Figure 1.

Note: Always place the negative (black) lead at the most negative (-) point and the positive (red) lead at the most positive (+) point.

(3) In figure 1 locate the 28V DC bus (+) and note that the wire coming off the bus is merely an extension of the positive power source going through a protective device (CB). Therefore, the wire is as equally positive at the power bus as it is at the pole of the switch.

b. Now let's look at the negative side of the circuit. Refer to figure 2. If you were to place the meter leads in the circuit as shown, the meter also would give an indication of "0" volts.

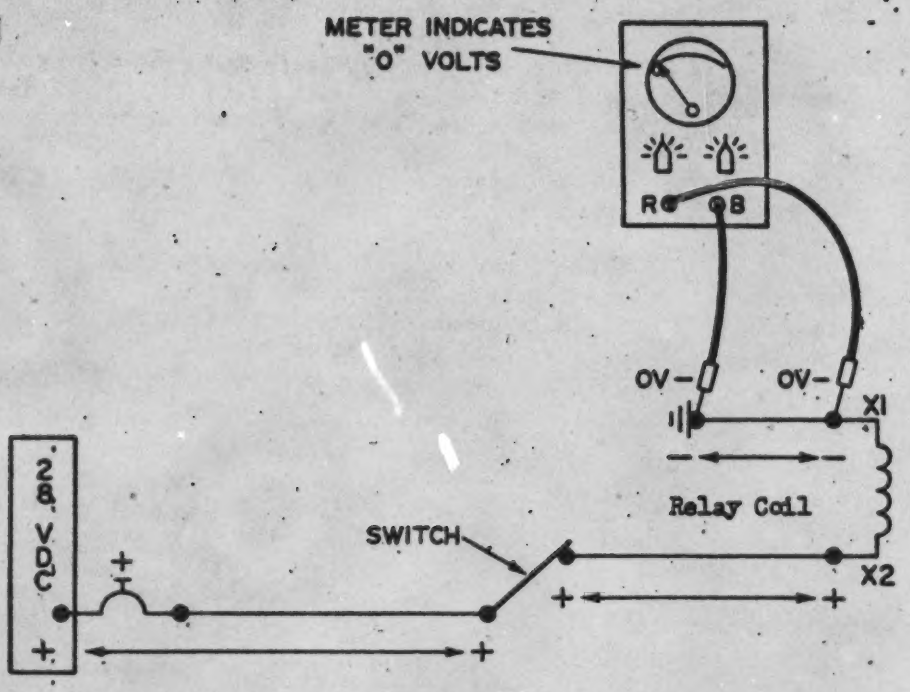

Figure 2.

(1) As you know there must be a voltage potential and/or drop in the circuit for the voltmeter to read. This normally caused by resistance (load) between the red and black leads when they are connected in a circuit.

(2) The ground wire is hooked from point X1 of the relay coil to the (⏚) ground point.

Note: Because of the reading of zero voltage in figures 1 and 2 these two wires are GOOD circuits WITHOUT opens.

c. IF you had a voltage reading on the negative side of the circuit in figure 2, which you should NOT have, it would stand to reason that something must be wrong with the circuit, but what?

(1) Refer to figures 2 and 3 and note in figure 3 that the ground wire for this circuit is broken (which will automatically make the circuit not work). Note the way the meter is connected in figure 3. The 28V DC reading is caused by the (high resistance) open wire in the ground circuit.

(a) There is a definite voltage difference in the ground circuit in figure 3.

(b) Only one side of the broken ground circuit in figure 3 is now physically connected to just the positive side (+) of the circuit. This is the part of the ground circuit connected to X2 of the relay coil.

(c) The other side of the broken ground circuit in figure 3 is physically connected to the negative side (-) ground point of the circuit.

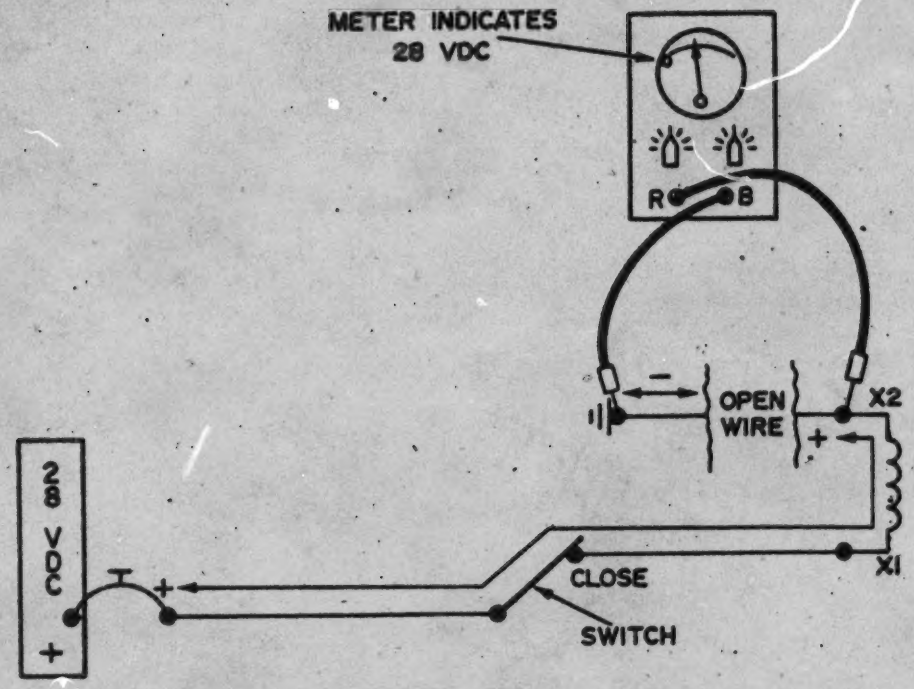

Figure 3.

(d) The black meter lead is connected to the negative side in figures 2 and 3.

(e) The red meter lead is connected to the positive side in figures 2 and 3.

1 The meter reads the difference between the two points (+ to -). This is because of the broken ground wire. If the wire was not broken you would have the conditions as shown in figure 2, a good circuit.

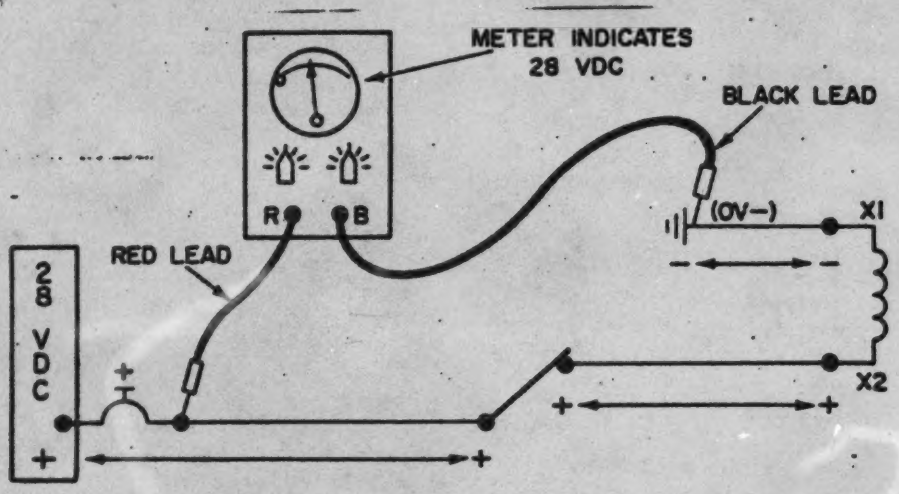

Figure 4.

d. Now let's see how the meter MUST be connected to the circuit to get a voltage reading. In figure 4 note that the black meter lead has been placed at the common ground point, further note that the RED meter lead is placed at the circuit breaker checkpoint.

(1) The voltmeter in figure 4 will now indicate a reading of 28V DC. Why? This is because of the distinct difference between the (+) and (-) points caused by the resistance (relay coil) between the two meter test points in the circuit. This voltage reading is obtained with power on.

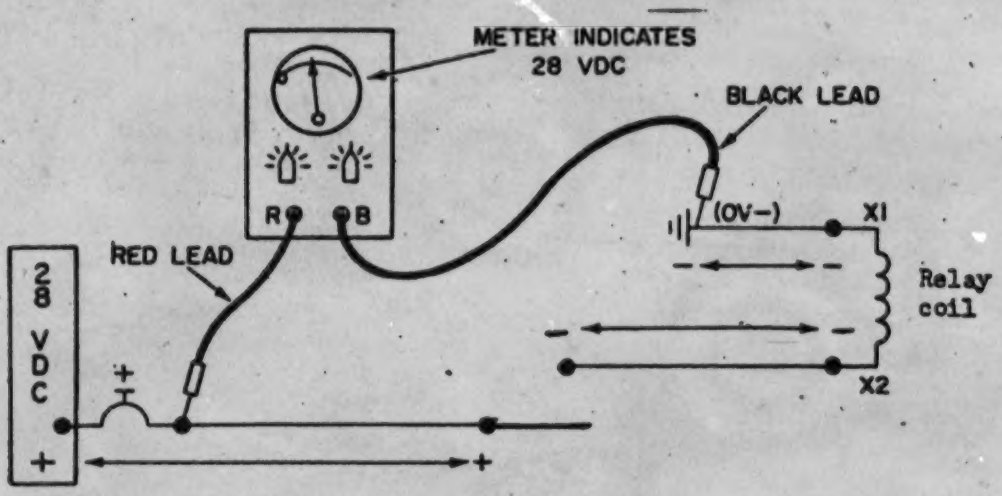

Figure 5.

(2) In figure 5 there is infinity resistance in the open contacts of the switch. The open in the switch is a NORMAL condition if the switch is turned to the OFF position. This causes the meter to read 28V DC as shown in figure 5. Remember back in figure 4 the meter also read 28V DC. This was with the switch closed and the reading was caused by the resistance of the load (relay coil).

Note: Compare the polarities (+) and (-) on X2 from figures 4 and 5. They changed because of the switch position.

e. Let's take another reading of this circuit in figure 6. Take a reading from X2 of the relay to the ground point. Note in figure 6 how the meter leads are connected. The black at the most negative (-) point and the RED at the most positive (+) point in the circuit being measured.

(1) Again the meter will indicate a reading of 28V DC. Because here again there is a difference in potential between the positive (+) and negative (-) sides of the circuit, which is the relay coil (load).

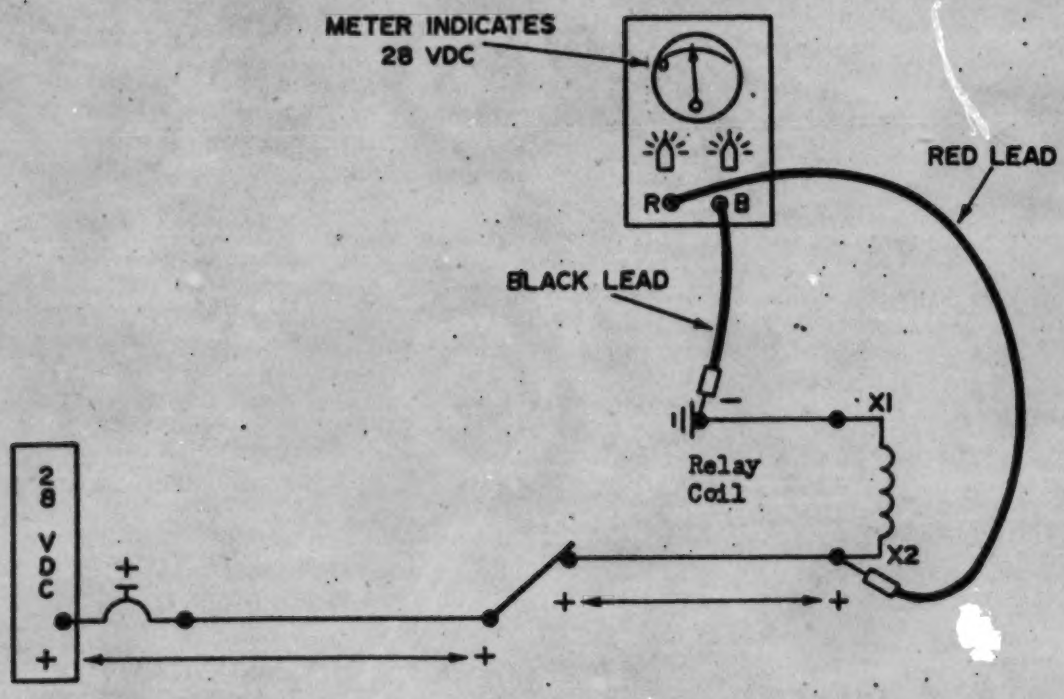

Figure 6.

NOTE AND REMEMBER: In order for the multimeter to indicate voltage, there must be a voltage potential or a difference between positive (+) and negative (-) which is normally caused by a resistance (load, open, high resistance, etc.) between them. When you start to take a voltage reading, you should "automatically ground" your black meter lead.

Exercise 1

Caution: Remove watches, rings, bracelets, etc., before starting any work on the trainer. It is also a good safety practice to work on the trainer with only one hand. This practice reduces the chances of receiving an electrical shock to some vital body organ when working with voltage.

1. Trainer Troubleshooting: Before you can effectively troubleshoot the DC motor trainer, you must become thoroughly familiar with the normal operation of the system. An operational checkout MUST be performed prior to troubleshooting to determine the condition of the system and to help you locate exactly which portion of the system is defective. Knowing when and how the systems operate normally is the key to successful troubleshooting.

2. Follow the procedures below and perform an operational check of the system with relay R3 energized.

a. Insure all (4) circuit breakers are pulled out.

b. Place control switch in the OFF position.

c. Place transfer switch in the OFF position.

d. Place all trouble switches toggles to the OUT position. These are located on the back of the trainer.

e. Insure trainer is plugged in.

f. Push in all four (4) circuit breakers. This supplies 28V DC for the system.

g. Place the TRANSFER switch to the ON position. Leave the TRANSFER switch ON for exercise 1. When the TRANSFER switch is turned ON relay #3 will be energized.

Note: If you have any questions at this time see your lab instructor. As you perform each of the following steps, place an X in the blank that correctly indicates relay or motor position. You will observe the motor valve operation and also study the electrical diagram on the trainer to answer the questions.

h. Place the CONTROL switch to the CLOSE position and insure the TRANSFER switch is in the ON position.

(1) Which relay should and did energize?

_____(a) Relay #1 (close relay)

_____(b) Relay #2 (open relay)

(2) Which motor valve opened?

_____(a) Motor valve #1

_____(b) Motor valve #2

(3) Which motor valve closed?

_____(a) Motor valve #1

_____(b) Motor valve #2

(4) Should R3 be energized?

_____(a) No

_____(b) Yes

i. Place the CONTROL switch in the OPEN position and insure the TRANSFER switch is in the ON position.

(1) Which relay should and did energize?

_____(a) Relay #1 (close relay)

_____(b) Relay #2 (open relay)

(2) Which motor valve opened?

_____(a) Motor valve #1

_____(b) Motor valve #2

(3) Which motor valve closed?

_____(a) Motor valve #1

_____(b) Motor valve #2

(4) Should R3 be energized?

_____(a) No

_____(b) Yes

This completes the operational check procedures with R3 energized, now compare your answers to those given. This way you will know that the trainer is operating normally.

Correct responses to Exercise 1:

h.	(1)	a	i.	(1)	b
	(2)	b		(2)	a
	(3)	a		(3)	b
	(4)	b		(4)	b

If all of your answers agree with those given above, you are now ready to begin operational check with transfer switch OFF (R3 deenergized). If your answers do not agree, perform the operational check again or ask your instructor for assistance.

Exercise 2

1. Following the procedures below, perform an operational check of the system with relay R3 deenergized.

a. Insure all circuit breakers are in and power is applied to the trainer.

b. Place the TRANSFER switch to the OFF position.

c. Place the CONTROL switch in the OFF position.

d. Insure all trouble switches toggles are to the OUT position. These are located on the back of the trainer.

Note: If you have any questions at this time see your lab instructor. As you perform each of the following steps, place an X in the blank that correctly indicates relay or motor position. You will observe the motor valve operation and also study the electrical diagram on the trainer to answer the questions.

e. Place the CONTROL switch to the CLOSE position, and insure the TRANSFER switch is in the OFF position.

(1) Which relay should and did energize?

_____(a) Relay #1 (close relay)

_____(b) Relay #2 (open relay)

_____(c) Relay #3 (transfer relay)

(2) Should motor valve #2 have opened?

_____(a) No

_____(b) Yes

(3) Should motor valve relay #2 have closed?

_____(a) No

_____(b) Yes

(4) Should motor valve #1 have opened?

_____(a) No

_____(b) Yes

(5) Did motor valve #1 close?

_____(a) No

_____(b) Yes

(6) Is relay R2 energized?

_____(a) No

_____(b) Yes

(7) Is relay R3 energized?

_____(a) No

_____(b) Yes

f. Place the CONTROL switch to the OPEN position, and insure the TRANSFER switch is in the OFF position.

(1) Which relay is energized?

_____(a) Relay #1 (close relay)

_____(b) Relay #2 (open relay)

_____(c) Relay #3 (transfer relay)

(2) Should motor #2 valve have opened?

_____(a) No

_____(b) Yes

(3) Should motor valve #2 have closed?

_____(a) No

_____(b) Yes

(4) Should motor #1 valve have opened?

_____(a) No

_____(b) Yes

(5) Should motor valve #1 have closed?

_____(a) No

_____(b) Yes

(6) Is relay R1 energized?

_____(a) No

_____(b) Yes

(7) Is relay R3 energized?

_____(a) No

_____(b) Yes

This completes the operational check procedures with R3 deenergized, now compare your answers to those given. This way you will know that the trainer is operating normally.

Correct responses to Exercise 2:

e.		f.	
(1)	a	(1)	b
(2)	a	(2)	a
(3)	a	(3)	a
(4)	a	(4)	b
(5)	b	(5)	a
(6)	a	(6)	a
(7)	a	(7)	a

Exercise 3

If you are thoroughly familiar with the normal operation of the system you will now start with troubleshooting. If you are in doubt about the normal operation of the system, see your lab instructor.

1. Follow the procedures below to program a cause for a malfunction in the trainer.

a. Insure power is connected to the trainer. See your lab instructor if needed.

b. Insure the CONTROL switch is in the OFF or center position.

c. Insure TRANSFER switch is in the OFF position.

d. Insure the circuit breakers (CB) are pushed in.

e. Sign out a multimeter and insure it is properly set up and leads connected to the meter. Place the meter in the meter box on top of the trainer.

Note: As you can see on the wiring diagram, the bus bar has 28V DC and the multimeter must be set up for these values.

f. Insure that all the trouble switches on the back of the trainer are in the OUT position.

g. Now place trouble switch #2 on the back of the trainer to the IN position.

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1. Now you are ready for the operational check of the system. Remember you are now looking for a visual malfunction of the valve(s) during the operational check.

Note: You are going to use trouble switch #2 on the back of the trainer for the first practice malfunction. The trouble switch on the back of the trainer when placed to the "IN" position will place a trouble in the electrical control circuit giving a malfunction. Because the location of the cause for the malfunction is unknown to you in the circuit, you will need to perform a complete operational check and then troubleshoot the malfunctioning circuit with a multimeter. Once you have moved a trouble switch to the IN position you will leave it there until this workbook and/or instructor instructs you otherwise.

a. Place the CONTROL switch to the OPEN position.

(1) What has happened? Motor valve #1 should be in OR is going to the OPEN position. Is this normal operation? From your studies you know it is correct.

b. Place the TRANSFER switch to the ON position.

(1) What has happened? Motor valve #2 should be in OR is going to the CLOSE position. Is this normal operation? From your studies you know it is correct. (Motor valve #1 OPENS and then motor valve #2 CLOSES.)

Note: You can look through the clear plastic cover on motor valve #1 and observe the action of the armature shaft rotating the cam lobe toward the limit switch. On both motor valve assemblies you can observe the valve butterfly movement through the clear plastic covers.

c. Place the TRANSFER switch in the OFF position and CONTROL switch in the CLOSE position.

(1) What happened? Motor valve #1 should but did not CLOSE. The TRANSFER switch is in the OFF position which will not allow motor valve #2 to operate.

(2) Refer to the practice problem chart on page 17. Make the correct entry under the malfunction OFF column. The entries made will be one of the letters shown below in that chart which identifies the correct malfunction. Trouble switch #2 has already been completed. The letter G (motor valve #1 will not close) is entered in the OFF column. This is because the TRANSFER switch is in the OFF position.

d. Insure the control switch is in the CLOSE position and place the TRANSFER switch in the ON position.

(1) What happened? Motor valve #1 would be but is not CLOSED and motor valve #2 did not OPEN. This is the observable malfunction because you can see what DID NOT happen through the plastic covers on the motor valve assemblies. (Motor valve #1 will not CLOSE and motor valve #2 will not OPEN.)

(2) Refer to the practice chart on page 17. Make the correct entry under the malfunction ON column. The entry made will be one of the letter(s) shown below the chart which gives the correct malfunction. The letter A (motor valve #1 will not CLOSE and motor valve #2 will not OPEN) is entered in the ON column.

(3) This observable malfunction should tell you that the CAUSE of the malfunction is in the CLOSE control circuit for motor valve #1. As you know, motor valve #1 must complete an operation before motor valve #2 will operate.

Exercise 5

1. Now you are ready to troubleshoot the control circuit and to find the CAUSE for the observable malfunction (motor valve #1 will not CLOSE and motor #2 will not OPEN). You will use the voltage measuring method of troubleshooting. This procedure starts at the connector plug of the malfunctioning unit (load) or motor winding. You will take the first voltage measurement on the positive side of the unit (load) which failed to function. Having the correct amount of power in the positive circuit up to the malfunctioning unit (load) indicates that the positive circuit is OK. This first voltage check taken at the plug will tell you to continue troubleshooting the positive (close) control circuit or troubleshoot the ground circuit. IF the voltage reading is below the required value of 28V DC, you would continue troubleshooting in the positive (close) control circuit. IF the required value of 28V DC is measured you would then check out the ground circuit for the malfunctioning load.

Follow the following instructions to solve for the cause of the malfunction.

a. Connect the BLACK lead from the meter to the common ground point on the trainer. This point is located on the front of the trainer between the two motor valve units. The BLACK lead will stay there during the following voltage measurements.

(1) This is the common ground for all units (relays and motors) in the control circuit.

b. Use the RED lead and measure the applied voltage on the positive side of the malfunctioning unit (load).

(1) The failing unit (load) is the close winding in the motor #1.

(2) Because BOTH valve motors failed to operate as recorded in the practice problem chart, you must start troubleshooting with motor valve #1. This is because motor #1 must complete its function BEFORE motor valve #2 can operate.

(3) You will begin measuring on the positive side of the malfunctioning load. Use pin B on the connector plug of the motor valve #1 for this. Place the RED lead on pin B and read the meter. Pin B is connected to the motor winding on the positive side.

(4) The meter reading on point B on motor valve #1 is OV DC (should be 28V DC) and this OV DC indicates the positive (CLOSE) control circuit has failed. This means you will now troubleshoot only in the positive (CLOSE) control circuit for the CAUSE for the malfunction.

Note: IF at point B you had a normal voltage reading of 28V DC, this reading would indicate a good positive CLOSE control circuit and then you would check out the ground circuit (point E motor valve #1). You will check out the ground circuit ONLY IF the positive circuit is OK.

c. Because you now know the malfunction is in the positive CLOSE control circuit, you must move the RED lead to the next point (junction) A2 of R1. Remember because of the low voltage you are looking for the 28V DC power in the circuit. You will have to follow wire H1B18 to junction A2. The meter reading at A2 is also OV DC and this should tell you to move across the armature of the relay to A1.

Note: Why? Because the voltage comes from the bus bar and you will troubleshoot from the load to the power source, trying to find where the 28V DC power has stopped in the positive control circuit before it reaches the load. This location will help you identify the cause.

d. The next check point (junction) is A1 of R1. This meter reading on A1 of 28V DC indicates that from this point to the 10A circuit breaker is a good circuit, and you will not need to check the voltage at the circuit breaker.

Note: Remember voltage, power, current will not at anytime FLOW through OR in the dotted line in the relay symbol.

e. The power on one side of the relay armature, (point A1) but NOT on the other side (point A2) indicates the armature didn't CLOSE.

f. To find out why the relay armature didn't close you must now troubleshoot the positive relay control circuit. Being that the relay coil is a load on this circuit you will now troubleshoot by measuring with the RED lead at the positive side of the relay coil (load) connection, X2 of R1. The meter reading at point X2 of R1 is 28V DC. This indicates the positive circuit for the relay coil is functioning normally.

Note: Only IF point X2 of R1 was reading OV DC would this indicate a failing positive circuit for the relay coil. IF this was the case, you would continue troubleshooting further into the positive relay circuit, through the control switch to

and through the circuit breaker IF needed. Remember, only IF both positive and negative circuits checked out OK for the relay coil, then the load (coil) itself may have failed internally and you would replace it.

g. You should have checked out the positive side of the circuit to the relay coil and found it is OK. Now, because the relay is still inoperative you must check out the negative circuit of the relay coil. This is done by measuring the voltage at X1 of R1. You should normally read 0V DC but you find an unwanted 28V DC power at this point, this indicates an open ground circuit for the relay coil. Remember, without the relay functioning correctly it will cause a malfunction on motor valve #1.

(1) Identify the malfunction by writing in the letter(s) which identifies the malfunction. Only one letter in each column if required. (These have already been done for you.)

(2) Complete the cause columns by writing in the (type of trouble) and (unit or wire number). These have already been done for you.

(3) See your lab instructor if you have any questions at this time.

h. Referring to the practice chart on page 17 and you will find all the required entries already made for trouble switch #2. Study the entries made to acquire knowledge on how to make the entries for the remaining trouble switches. You will also find that you have two (2) malfunction columns. You will complete both columns as needed.

Exercise 6

You have completed troubleshooting trouble #2. You should be able to troubleshoot a malfunction on your own at this time. You may ask for assistance from the lab instructor, if necessary.

1. Follow the procedures below to troubleshoot a malfunction in the trainer that you will do for practice.

a. Insure power is connected to the trainer. See your lab instructor if needed.

b. Insure CONTROL switch is in the OFF or center position.

c. Insure TRANSFER switch is in the OFF position.

d. Insure circuit breakers are pushed in.

e. Insure multimeter is properly set up and leads are connected to the meter.

f. Insure that all the TROUBLE switches on the back of the trainer are in the OUT position.

g. See the instructor to have a TROUBLE switch # entered in for the practice problem and progress check charts on pages 17 and 19.

h. Now place the TROUBLE switch # entered on the practice problem chart to the IN position on the back of the trainer.

2. Perform an operational check.

3. Complete both malfunction columns transfer switch "ON" and "OFF" as required. (If there is an X in one of the blocks, no entry is required.)

4. Troubleshooting the circuit(s) for the cause.

5. Complete both CAUSE columns.

6. Check the wire number against your entry in the malfunction columns for a recheck of your work. Note: Remember how you did your wiring diagram workbook in the classroom, use that knowledge to cross check this work.

7. Have your instructor check and initial your work before progression. If your work is incorrect follow the instruction given by the instructor.

Practice Problems

Trouble Switch Number	Malfunction Transfer Switch		Cause	
	ON	OFF	Type of trouble open, short, etc.	Unit or wire Number
2	A	G	open	H5D18N
		X		

A. Motor 1 will not close and motor 2 will not open.

B. Motor 1 will not open and motor 2 will not close.

C. Motor 1 and 2 inoperative.

D. Motor 2 will not open.

E. Motor 1 inoperative.

F. Motor 2 inoperative.

G. Motor 1 will not close.

H. Motor 1 will not open.

I. Motor 2 will not close.

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Note: The circuit malfunction must describe exactly what is malfunctioning, nothing more or less. Always note the position of the control switch, transfer switch, and motor limit switch.

Instructor's Initials _____ Practice Problem Grade _____

If your lab instructor signs off your practice work you will be assigned your progress check material.

Exercise 7

PROGRESS CHECK INSTRUCTIONS

This progress check will require you to correctly solve a minimum of 4 out of the 5 problems given. This should be accomplished in much the same manner as the practice problems. The instructor will check and initial your work after the 5 problems are graded and passed. If you have missed more than one (1) problem you will follow the instructions of your lab instructor.

You will not communicate (talk, etc.) with other students during the progress check without your lab instructor's permission.

You will not use fellow students' work to solve the problems in this progress check.

You must satisfactorily complete this progress check before further progression to other lab troubleshooting projects.

Note: If any part of the answers (cause or malfunction) to the trouble switch # is wrong, the instructor will mark the whole trouble switch entry incorrect. This means YOU will have to find what part or parts of the cause or malfunction is incorrect for that trouble switch.

Students will please complete the following (print).

STUDENT'S NAME _____
Last First

DATE PROGRESS CHECK STARTED _____

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PROGRESS CHECK						
Trouble Switch Number	Malfunction		Cause		Instructor assist Initial	
	Transfer ON	Switch OFF	Type of trouble open, short, etc.	Unit or wire number	1st	2nd

A. Motor valve 1 will not close and motor valve 2 will not open.

B. Motor valve 1 will not open and motor valve 2 will not close.

C. Motor valve 1 and 2 inoperative.

D. Motor valve 2 will not open.

E. Motor valve 1 inoperative.

F. Motor valve 2 inoperative.

G. Motor valve 1 will not close.

H. Motor valve 1 will not open.

I. Motor valve 2 will not close.

Before you have your instructor check your work, recheck it yourself like you did in the practice problems.

Instructor's Initials _____ Complete Progress Check Grade _____

Whether you have failed or passed this progress check, you will follow the instructions given to you by the lab and/or classroom instructor.

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If you have satisfactorily completed the progress check, store your multimeter and trainer in the following way.

1. Pull out all the circuit breakers (4) each.

2. Place the control switch in the OFF position.

3. Place the transfer switch in the OFF position.

4. Place all trouble switches toggles to the OUT position. These are located on the back of the trainer.

5. Insure all your training literature, pencils, etc are taken with you when you leave the lab.

6. Insure your trainer and the area around it is clean before you leave the lab.

7. Properly store and sign in your multimeter before you leave the lab.

8. Check with the lab instructor before you leave the lab.

NOTE: Did you leave your multimeter set on OHM's? If you have go back and change it.

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PROGRAMMED TEXT

3ABR42231-PT-122

Technical Training

Aircraft Environmental Systems Mechanic

TEMPERATURE CONTROLLING BRIDGE CIRCUITS

16 February 1979

CHANUTE TECHNICAL TRAINING CENTER (ATC)
3370 Technical Training Group
Chanute Air Force Base, Illinois

Designed for ATC Course Use.

Do Not Use on the Job.

FOREWORD

This programmed text was validated in Course 3ABR42231 using 30 students from subject course. At least 90% of the students achieved all the objectives as stated. The average student required 2.6 hours to complete this lesson.

OBJECTIVES

Using Kirchhoff's Current, Voltage and Ohm's Laws, solve for unknowns in temperature controlling bridge circuits. A minimum of 8 out of 10 unknowns must be correct.

INSTRUCTIONS

This programmed text presents information in small steps called "frames." After each step you are asked to respond to the information in some way. Do not mark in this text. Read the material and make your response on the response sheet as directed by the frame. After you have made your response, compare your answers with the correct answers on the following page or next even numbered page. If you find you are incorrect, reread the frame to get the correct information. If you are right, and you understand the information presented in that frame, proceed to the next.

Remember, you are not graded on how fast you go. Do not rush, but do not loaf. You will be required to take a test at the end of this text to determine what you have learned. Since your learning in every frame usually depends on what you have learned in the preceding frame, DO NOT SKIP ANY FRAME.

Supersedes 3ABR42331-PT-114, 28 February 1975.
OPR: 3370 TCHTG
DISTRIBUTION: X
3370 TCHTG/TTGU-P - 400; TTVSA - 1

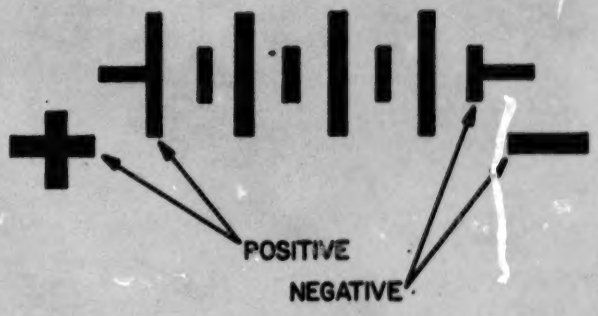
You are going to learn a circuit that is used extensively in aircraft environmental systems. It is called the automatic temperature control circuit. That's right--AUTOMATIC. It can actually decide the correct thing to do. Of course, we "program" its activity so it will make the right decisions.

If the pilot or a crew member wants to change the temperature in the cabin, he will simply turn a control knob. The system will automatically adjust to the temperature he selects. This system operates much like the heating and air conditioning system in your home. You simply set a thermostat to the temperature. Your furnace or air conditioner automatically maintains the temperature you select.

Do you recall the symbol for a battery? We thought it best if we presented the battery symbols again to refresh your memory.

A battery symbol is shown at the bottom of the page. Notice the symbol has long lines and short lines. The long lines indicate the POSITIVE terminals. The short lines indicate the NEGATIVE terminals of the battery.

Of course, the (+) sign indicates POSITIVE while the (-) sign indicates NEGATIVE



NO RESPONSE REQUIRED

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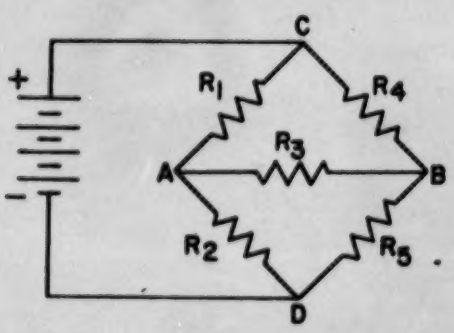
CORRECT RESPONSES TO FRAME 1: No response required.

Frame 2

The circuit that you will be working with is called a DC bridge circuit. This "bridge" is used to automatically control the temperature in the aircraft. You must know the basic structure of the circuit to learn how it automatically controls the temperature. Notice, the circuit has five separate resistors and a source of EMF (voltage). Notice that between points A and B the circuit shows resistor R-3. This resistor bridges across the parallel circuit making it a bridge circuit.

The circuit operates on the principle of a voltage potential between different points of the circuit, A and B. Notice, at point C the circuit parallels into two branches. The left branch is made up of resistors R-1 and R-2. The right branch is made up of resistors R-4 and R-5. The parallel circuits become a bridge only when connected together by resistor R3.

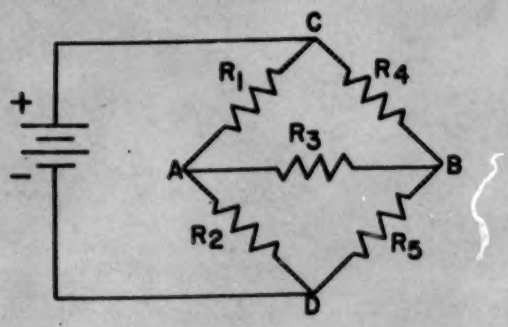


Complete the statements. Write your response on the response sheet.

1. The bridge circuit operates on the principle of a _____ of voltage between different points in the circuit.

2. The resistor that bridges the two parallel branches is resistor _____.

For a current to flow, a difference of voltage potential must exist between two points. If point A has a higher potential than B, current will flow across resistor R3. Also, if B is higher than A, current will flow across resistor R3.



It is necessary to know operation of a bridge to understand aircraft temperature control. You must know the structure of the circuit and the function of its components. Also, how each part of the circuit affects operation of the bridge. The following frames will go through computation of bridge voltages.

Answer the statement true (T) or false (F) on the response sheet.

Current can flow either from points A to B or from points B to A.

CORRECT RESPONSES TO FRAME 2: 1. potential or balance 2. R-3

CORRECT RESPONSES TO FRAME 3: True

Frame 4

Refer to page 49. Locate the diamond shaped diagram; it looks similar to the circuit shown in frame 3. Locate the points of the diamond, A, B, C, and D. If a difference in voltage potential exists between points A and B, there will be a current flow across the coil between these two points. This will energize the temperature control valve. It will then operate in one direction or the other.

For example, assume that the voltages are unequal and current flows from point A to point B. As current flows across the coil (located between A and B) the coil becomes magnetized. The right hand end becomes the north pole. This pushes the contact down on the right side. The close side of the temperature control valve is energized. As a result, this valve closes farther and allows more cold air to enter the cockpit.

Assume that current flows across the bridge from point B to point A. In this case, the coil becomes magnetized in the opposite direction. The left side of the contact is pushed down. The open side of the temperature control valve is energized. This allows more hot air to enter the cockpit.

Complete the statements. Write your responses on the response sheet.

1. If voltages between points A and B are equal there will be _____ across the bridge coil.

2. The temperature control valve is controlled by the _____ circuit.

3. If the voltages are unequal between points A and B, there will be _____ across the bridge.

The rest of the text describes the circuit function. To understand how the bridge operates you must compute voltages in series and parallel circuits. You must know how each point of the circuit relates to all other points. How to combine and compute series-parallel circuit voltages. Be able to determine how an unbalanced or balanced condition occurs.

Foldout #1 shows a bridge circuit controlling a temperature control valve. The valve gives either hot or cold air. The purpose of the bridge is to automatically control this valve. The valve, in turn, controls the aircraft temperature.

NO RESPONSE REQUIRED

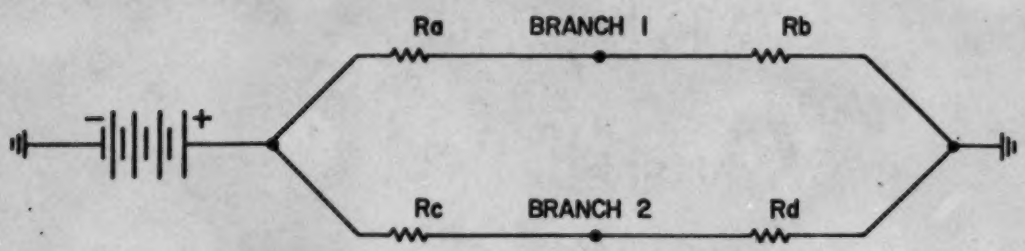
CORRECT RESPONSE TO FRAME 4: 1. no current 2. bridge

3. current flow.

CORRECT RESPONSE TO FRAME 5: No response required.

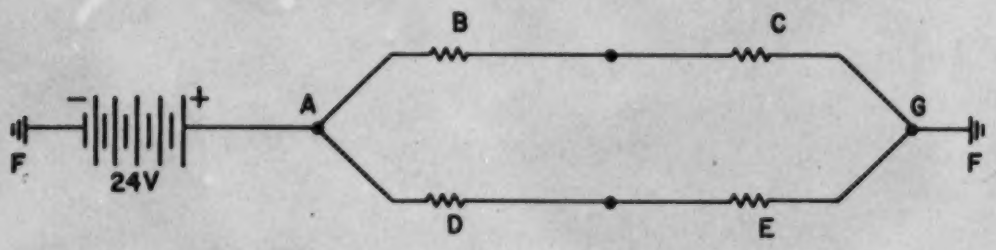
Frame 6

Previously, you studied series and parallel circuits. You observed the effects of current, voltage and amperage in these circuits. Before you can use these values you must determine which is a series or parallel circuit.



In the illustration above notice that resistors Ra and Rb are in series with each other. Resistors Rc and Rd are also in series with each other. Note that Ra and Rb make up Branch #1. Rc and Rd make up Branch #2. Notice that Branch #1 and Branch #2 are in parallel with each other.

Study the illustration below and answer the questions which follow.



Write the correct answers on the response sheet.

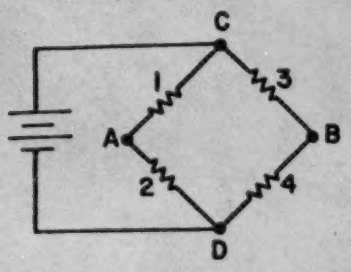
1. Points F are common (resistors) (grounds).

2. Resistors B and C are in (series) (parallel) with each other.

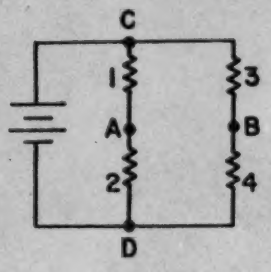
3. Resistors B and C are in (series) (parallel) with D and E.

4. Resistors D and E are in (series) (parallel) with each other.

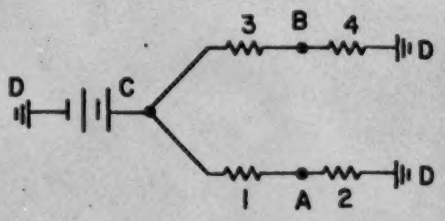
Resistors are placed in a circuit in many different ways. When they have certain things in common, they form a series-parallel circuit. Illustrations A, B, and C are a few circuit arrangements.



A



B



C

We have assigned numbers and letters to different points in the circuits. This will assist you in locating the points being discussed. The reference points must be known before the circuit can be analyzed and computed. Use illustrations A, B, and C to answer the statements on your response sheet.

1. Point C is located between resistors (1-3) (2-4) and is connected to the (+) (-) battery terminal.

2. Point D is located between resistors (1-3) (2-4) and is connected to the (+) (-) battery terminal.

3. The most positive point in these circuits is point (A) (B) (C) (D).

4. The most negative point in these circuits is point (A) (B) (C) (D).

CORRECT RESPONSES TO FRAME 6: 1. grounds 2. series 3. parallel

4. series.

CORRECT RESPONSES TO FRAME 7: 1. (1-3) (+) 2. (2-4) (-) 3. (C)

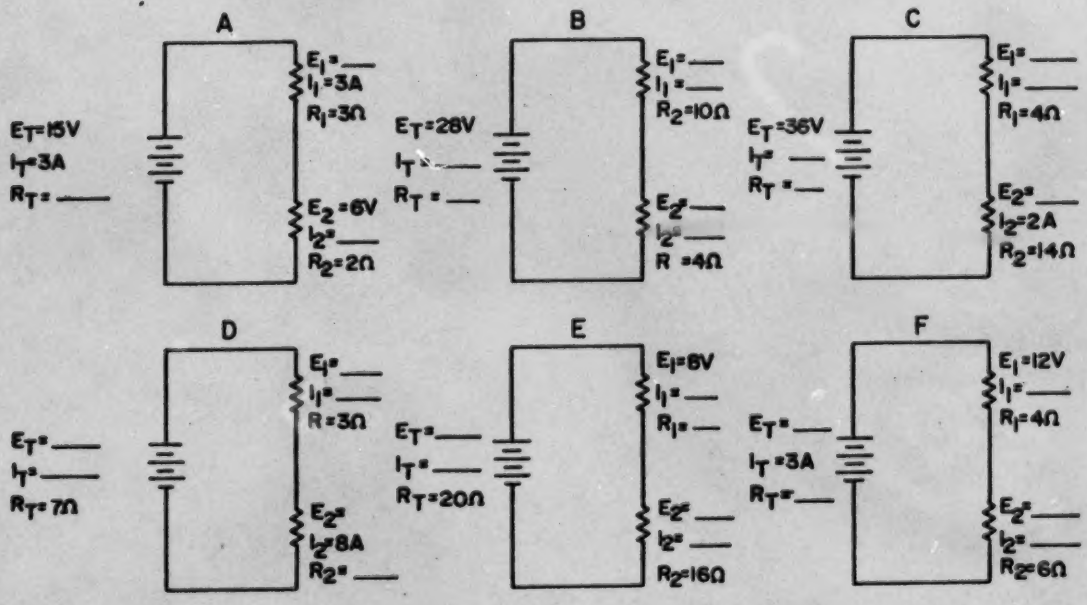
4. (D)

Frame 8

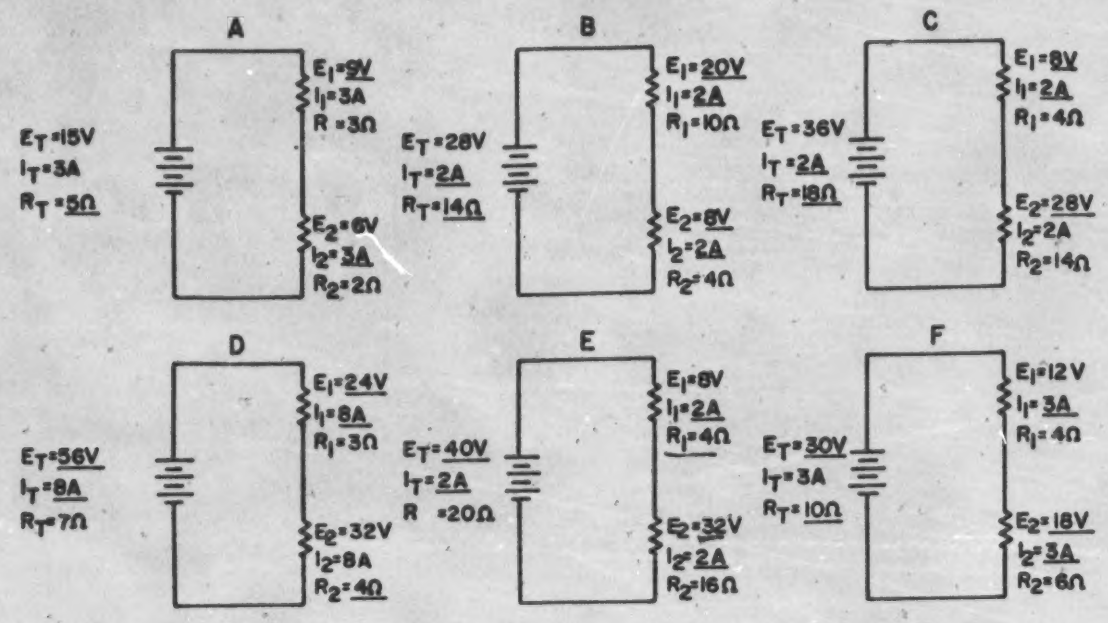
At this point let's have a quick review. Remember the rules for finding the totals of E, I, and R in a series circuit?

E_t = sum of voltages, I_t = same, and R_t = sum of all resistors in the circuits.

Apply Ohm's laws to solve the following series circuit problems. If you feel you need a review, refer to the text on series circuits, Kirchhoff's Current Law, Kirchhoff's Voltage Law and Ohm's Law as necessary. Use your response sheet to record your answers.

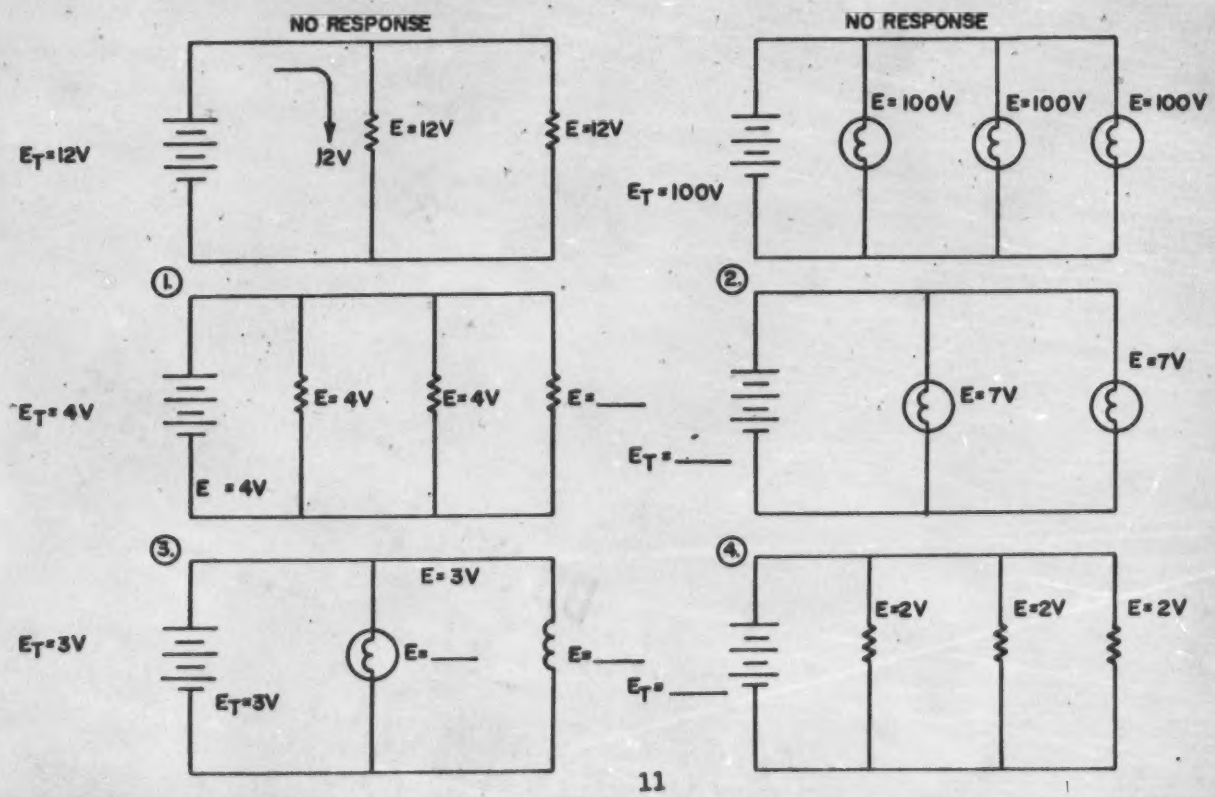


CORRECT RESPONSES TO FRAME 8:



Frame 9

When computing series-parallel circuit problems, the main application of Ohm's law you will be dealing with is voltage. Let's review the effect of voltage in a parallel circuit. In a parallel circuit voltage pushes with equal pressure across all branches. Or voltage has the same value in each branch of a parallel circuit. Solve the parallel circuit problems. Notice what happens to voltage.

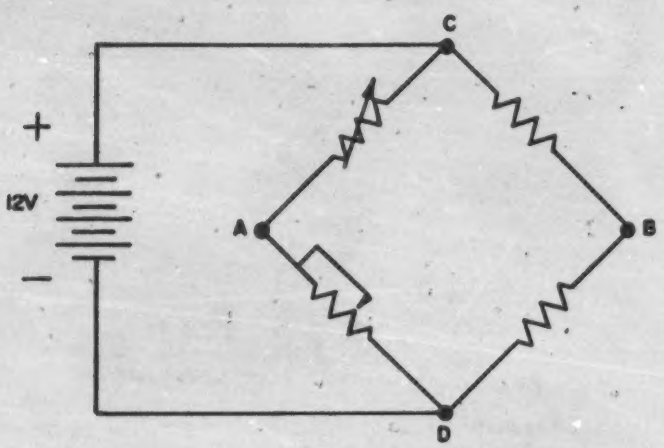


907

CORRECT RESPONSES TO FRAME 9: 1. E = 4v 2. E_t = 7v 3. E = 3v 4. E_t = 2v.

Frame 10

In a parallel circuit, remember that E_t = same, I_t = sum, and R_t = less than the least. In the figure below you will notice there is a 12 volt potential. This potential is at the positive (+) post of the battery. Also, 12 volts are impressed at point C of the circuit. Note, from the battery to point C there is only one path for voltage. Starting at point C you have two paths for voltage. The first path is from point C to point B to point D. One of the easiest ways to trace a voltage path is from the positive terminal of a power source to the negative point in a given circuit.



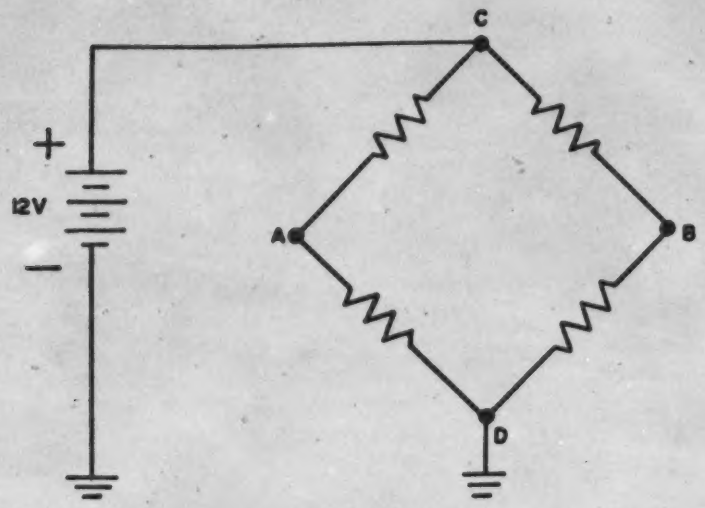
Write the correct answer for the statements below on the response sheet.

1. The easiest way to trace a voltage path in a circuit is from (negative to positive) (positive to negative).

2. Voltage drop (is the same) (differs) across all branches of a parallel circuit.

3. In the circuit above, there are 12 volts impressed at point (A) (B) (C) (D).

The circuit below is a series-parallel circuit. Study it closely. Remember that between points C and D the circuit divides into two series branches. When you see the two circuits, go on to Frame 12.



No Response Required

909

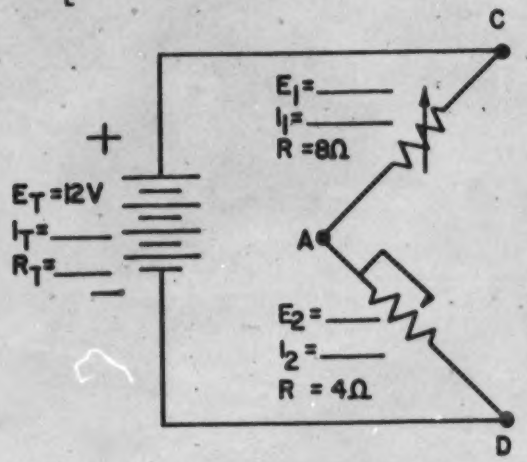
CORRECT RESPONSES TO FRAME 10: 1. positive to negative 2. is the same

3. c.

CORRECT RESPONSE TO FRAME 11: No response required.

Frame 12

To aid in computing the voltages and currents in a series-parallel circuit use a mask to cover the right side of the circuit. It would then appear as shown in the circuit below. You are now dealing with a series circuit. The circuit has two resistors in series with each other. Study the reading of the battery. The voltage total for the circuit is E_t = 12 volts.



Write your answers on the response sheet.

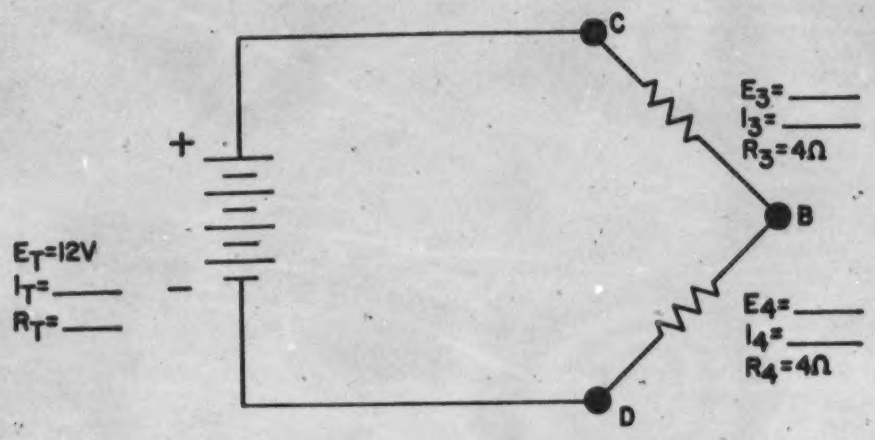
Look at resistors R_1 and R_2; you have been given the value of each resistor. If you add them together (R_1 and R_2), you can get the total resistance (R_t). Do so now and enter the resistance total on the response sheet.

You now have two complete values (E_t and R_t). Using Ohm's law find the rest of the totals. Use the formula

$$I_t = \frac{E_t}{R_t}.$$

When you have determined the current total (I_t) you have the key to the rest of the circuit. Remember the statement? "Throughout a series circuit, current flow remains the same." Simply stated; when one (1) amp of current flows through the first resistor, the same one (1) amp of current will flow through the rest of the resistors in series. Example: I_1 = 1A; I_2 = 1A. Find the rest of the values in the circuit.

The next step is to complete the right side of the series-parallel circuit. Follow the same procedures used in the preceding frame. Cover the left branch of the circuit. Your circuit should appear as shown. Remember, you are not required to compute this circuit as a parallel circuit. The only computation that you must know of a parallel circuit is that voltage potential is equally applied across each branch of the circuit. From there, the two branches are separated and treated as two separate series circuits.



Write your answer on the response sheet.

Using the information learned so far, compute the right hand side of the circuit. The totals formula (E_t = , I_t = , R_t =) will not be entered on the rest of the circuits. It will be necessary for you to set up your own formulas. When you first look at a circuit from now on, you should automatically set up the formulas.

911

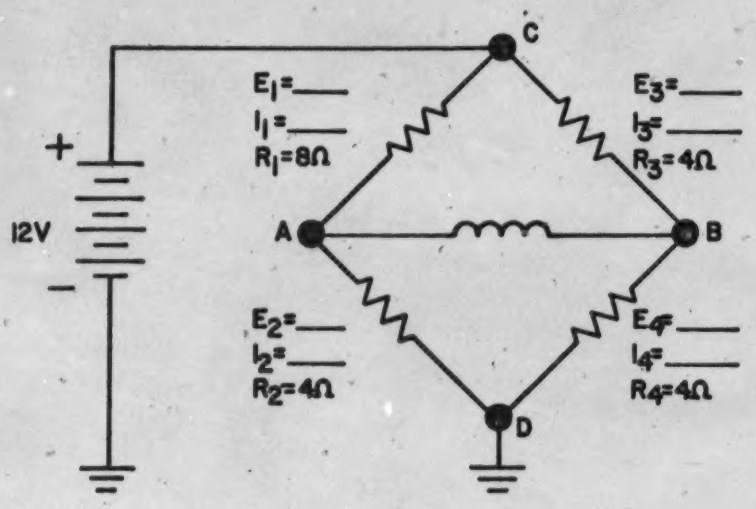
CORRECT RESPONSES TO FRAME 12: $E_t = 12v$, $I_t = 1_a$, $R_t = 12$; $E_1 = 8v$, $I_1 = 1a$, $E_2 = 4v$, $I_2 = 1a$.

CORRECT RESPONSES TO FRAME 13: $E_t = 12v$, $I_t = 1.5a$, $R_t = 8$, $E_3 = 6v$, $I_3 = 1.5a$, $E_4 = 6v$, $I_t = 1.5a$.

Frame 14

Let's combine what you know about a series and parallel circuit. Refer to the figure. Solve the following problems using Ohm's Law, Kirchhoff's Laws and the principles of series and parallel circuits on your response sheet.

Note: Remember at point C, voltage is equally applied across each circuit. Read the bottom paragraph before computing the bridge.

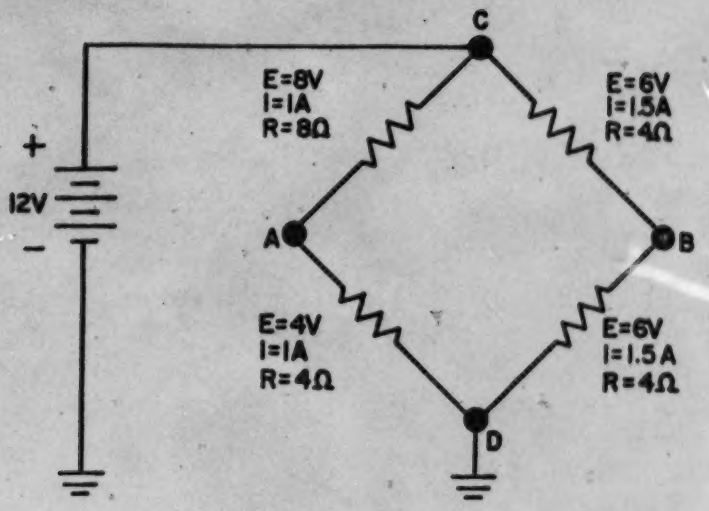


Remember, from point C you are dealing with two series circuits. Take your mask and cover the right path of the circuit (R_3 and R_4).

R_1 and R_2 now make up a series circuit. It must be computed as such.

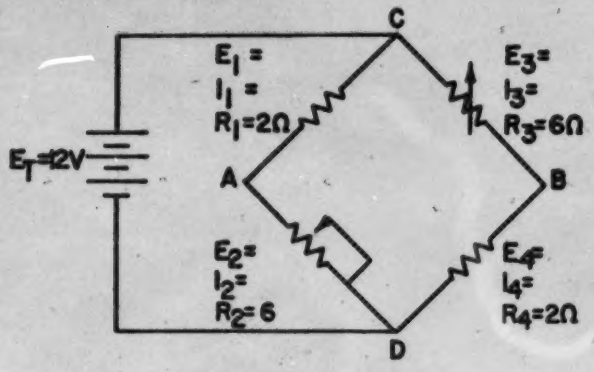
After completing the left path of the circuit, cover the left path and compute the right path. You now have resistors R_3 and R_4 in series. The circuit must be treated as such. You do not compute this circuit as a parallel circuit, except for the voltage factor being equally applied across each branch.

CORRECT RESPONSES TO FRAME 14:

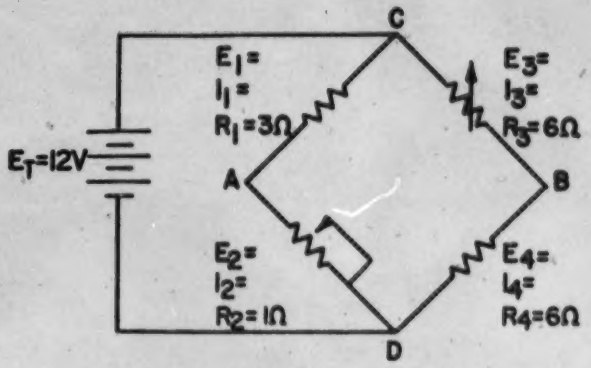


Frame 15

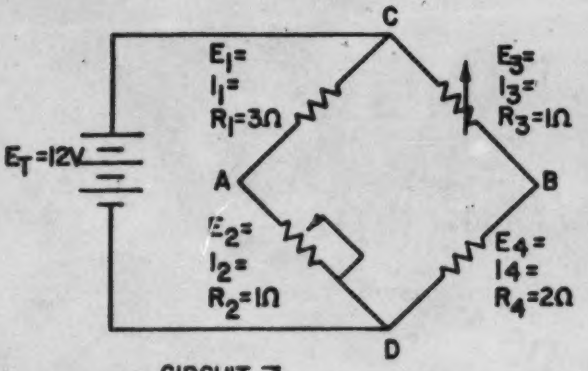
To aid you further in computing series-parallel circuits, we have listed four more that you must complete. Using the principles learned thus far. Write your answers on your response sheet.



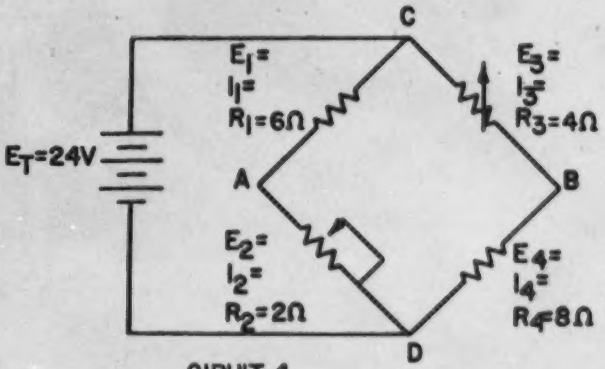
CIRCUIT 1



CIRCUIT 2



CIRCUIT 3

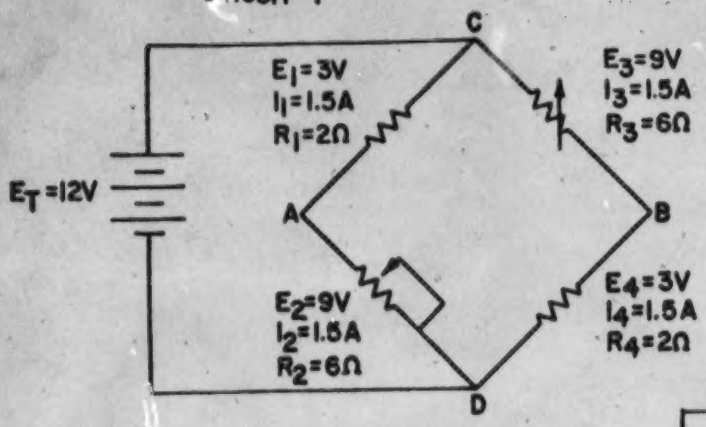


CIRUIT 4

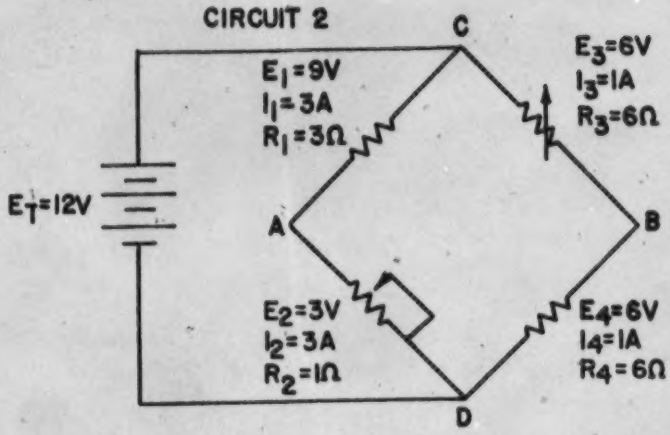
913

CORRECT RESPONSES TO FRAME 15:

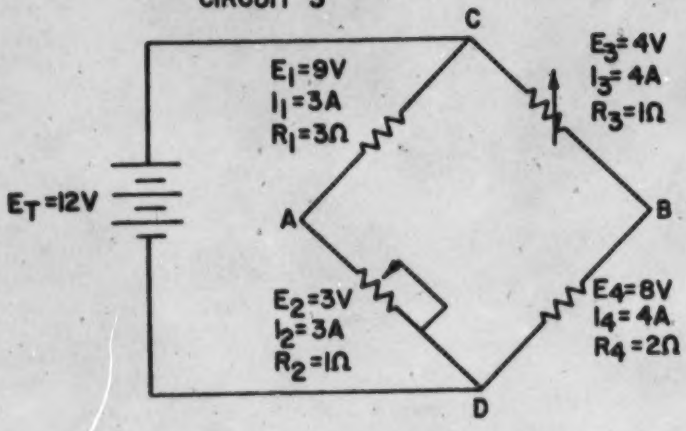
CIRCUIT 1



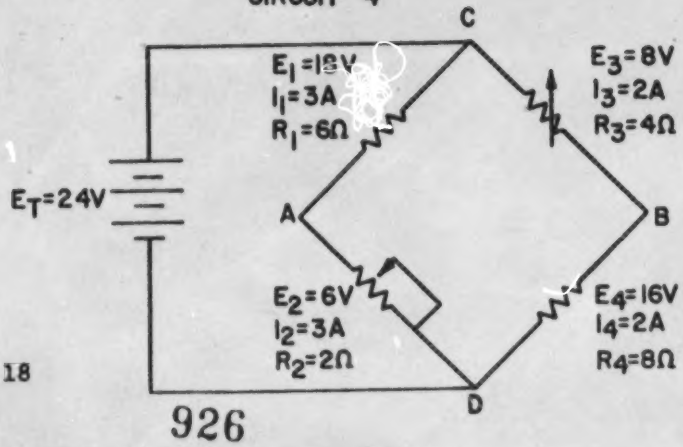
CIRCUIT 2



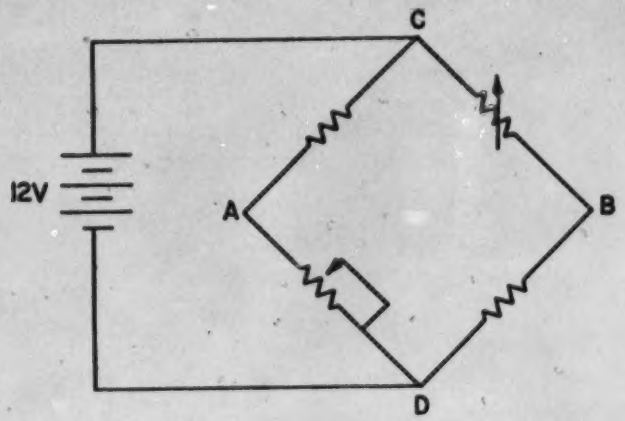
CIRCUIT 3



CIRCUIT 4



The next important step is defining voltage polarities at different points within the circuit. Remember, it was stated that point D is negative. It is connected to the negative terminal of the battery. In fact, point D is the most negative point in the circuit. Simply stated, if point D is most negative, nothing else could be more negative. If any other points are referenced to D they will always have to be positive. Read this information again; it will prove to be a key in determining bridge operation. Referring to the illustration, identify the correct polarity symbol in each statement. Write your answer on the response sheet.

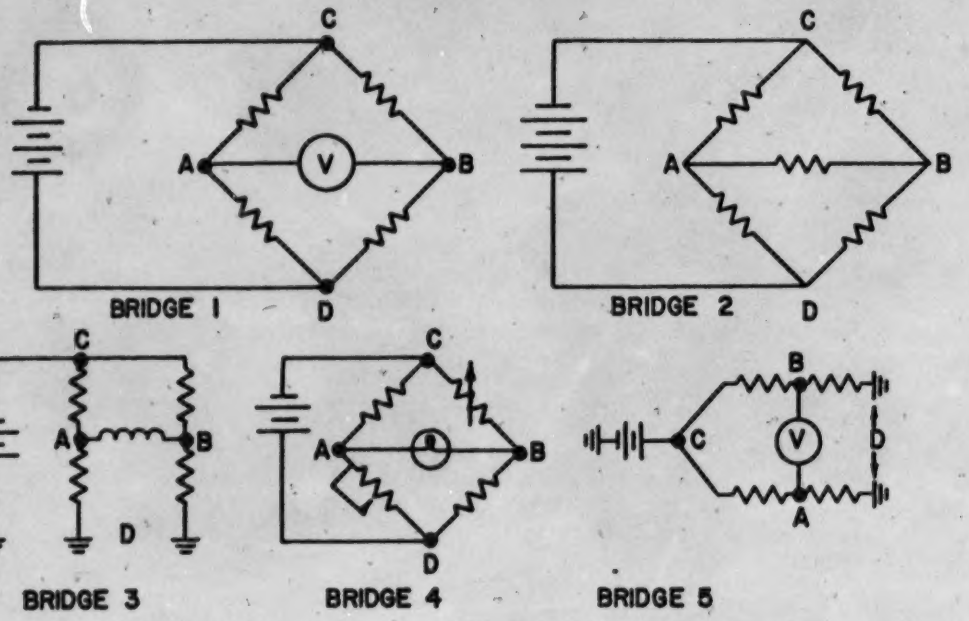


1. C is (+) (-) in respect to point D.
2. D is (+) (-) in respect to point C.
3. B is (+) (-) in respect to point D.
4. A is (+) (-) in respect to point D.
5. D is the most (+) (-) point of the circuit.
6. C is the most (+) (-) point of the circuit.

CORRECT RESPONSES TO FRAME 16: 1. (+) 2. (-) 3. (+) 4. (+) 5. (-) 6. (+).

Frame 17

Up to this point you have been dealing with series-parallel circuits. This type of circuit is necessary for a "bridge" circuit. What is a bridge? It is something that allows us to get from one point to another. An example is the Golden Gate Bridge. It allows you to get from one side of the Bay to the other without going around. Our bridge works on the same principle. We are going to bridge our circuits between points A and B. Below are some possible arrangements of bridge circuits. Notice, the paths that have been provided for current to flow from A to B or from B to A.



Did you notice that in bridge 1 we used a voltmeter, bridge 2, a resistor, bridge 3, a coil, bridge 4, a light bulb, and bridge 5, a voltmeter? Remember, to make a bridge, you can use various types of bridging devices.

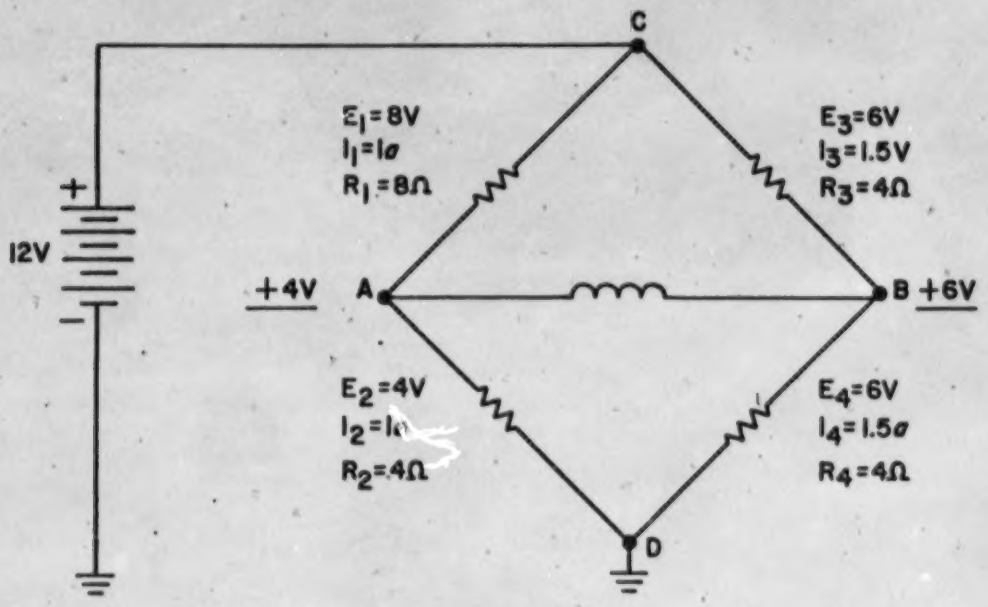
No Response Required

You have learned that voltage was "used up" in a circuit by pushing current through a resistance. Another term for the "using up" of voltage by a circuit is "voltage drop." Voltage drops in a series circuit are in proportion to the different resistances in the circuit. The total voltage drop is equal to the sum of the voltages. Voltage drop is determined by the resistance of the circuit.

In the circuit below, notice that resistor R_1 indicates 8 volts. What this means is, of the 12 volts available at point C, 8 volts are being used. The 8 volts will push 1 amp of current flow through this resistor. You have 4 volts remaining.

From resistor R_1 there is a wire to the top of resistor R_2. This wire offers very little resistance to current or voltage. The remaining 4 volts will not be used on this wire. The 4 volts will be used through resistor R_2.

It should be obvious at this point that no voltage is coming out of resistor R_2. The voltage difference between C and D is 12 volts. All the voltage is used by the circuit to push current through both resistors. A voltage reading to ground at point D is zero volts.



Using point D as reference in the diagram above, complete the following statements by writing your answer on the response sheet.

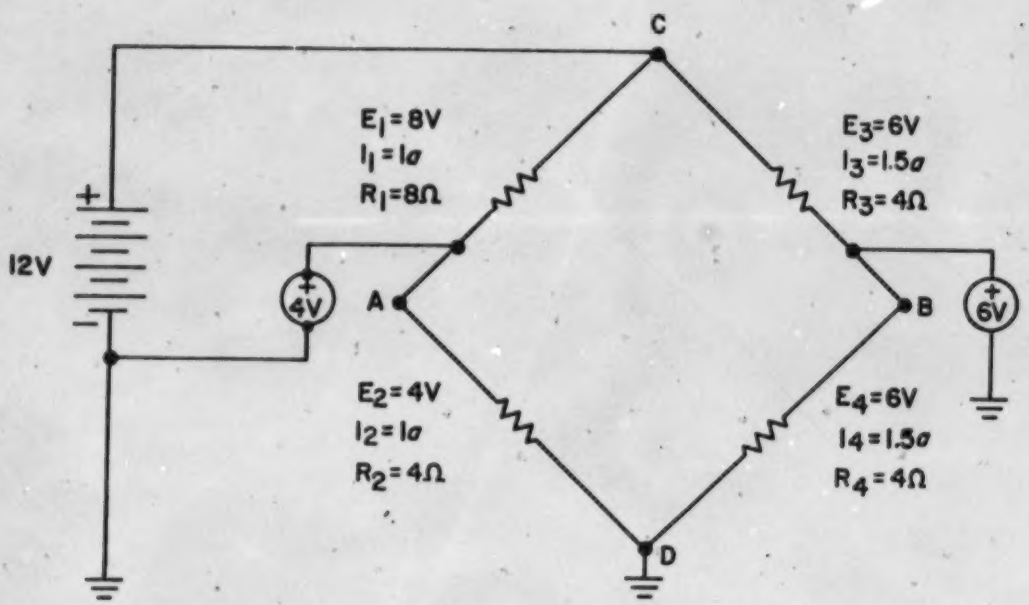
1. Voltage potential at point C is _____ volts (+) (-).
2. Voltage potential at point D is _____ volts (+) (-).
3. Voltage potential at point B is _____ volts (+) (-).

917

CORRECT RESPONSES TO FRAME 18: 1. 12v+, 2. 0v, 3. 6v+.

Frame 19

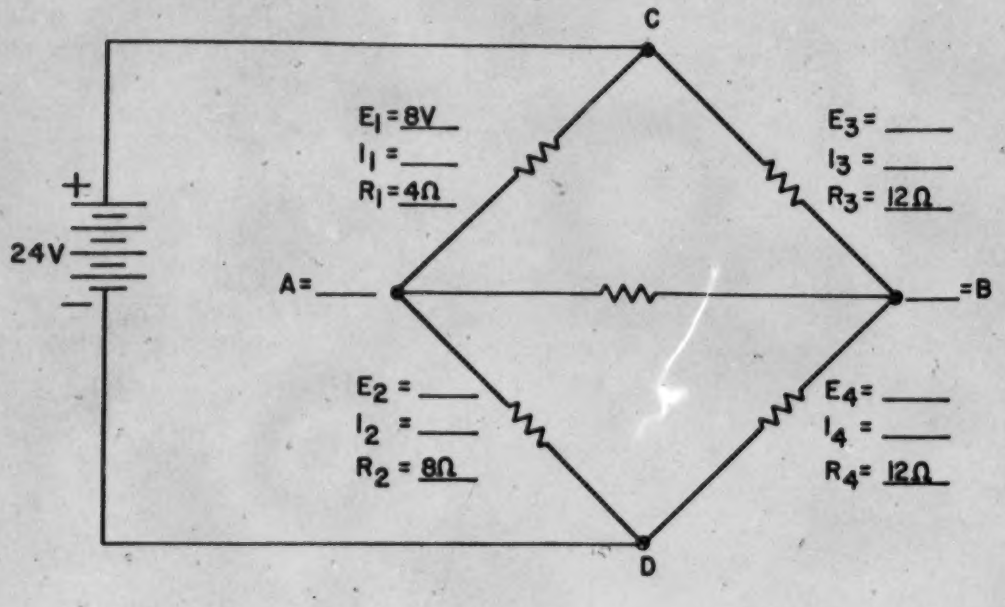
A bridge circuit has two legs; points CAD and points CBD. Look at the right leg (CBD) of the bridge circuit. It takes 6 volts (V) of the 12V potential at point C, to cause 1.5 amps to flow through R_3 to R_4. The remaining 6V can be found at any point on the wire between R_3 (-) and R_4 (+). Notice how the voltmeter is connected around point B. The voltmeter would indicate a + 6V potential at point B. Remember, current flows from positive (+) point C to negative (-) point D. The remaining 6V pushes the 1.5 amps through R_4. The potential of 12V at point C is used to force 1.5 amps through R_3 and R_4. The voltage potential at point D is zero. Another thing to consider; the voltage value of point B is -6V in relation to point C, and +6V in relation to point D. This is also true for the left leg (CAD) of the bridge circuit. Point A has a - 8V in relation to point C and + 4V in relation to point D. Point D is ground (-) and has a voltage relation of - 0V to point C. The voltage potential at point C is + 12V.



Complete the statements by writing your answer on the response sheet.

1. The voltage at point C is _____.
2. The voltage drop across R_1 is _____.
3. The voltage drop across R_2 is _____.
4. The voltage drop across R_3 is _____.
5. The voltage drop across R_4 is _____.
6. The voltage drop across CAD is _____.
7. The voltage drop across CBD is _____.
8. The voltage at point D is _____.

Solve for the missing value in the bridge circuit below and answer the questions which follow. Use point D as a reference point. Determine the voltages and polarities at points A and B. Write your answers on the response sheet.



Complete the statements.

1. I_1 and I_2 = _____ amps.

2. Voltage at point A is _____ volts and is (+) (−).

3. Point B is _____ volts and is (+) (−).

4. Point _____ is the reference point of the bridge and all points in reference to it are (+) (−).

5. The difference between voltages at point A and B is _____ volts.

6. Point D should indicate a _____ voltage reading on a voltmeter.

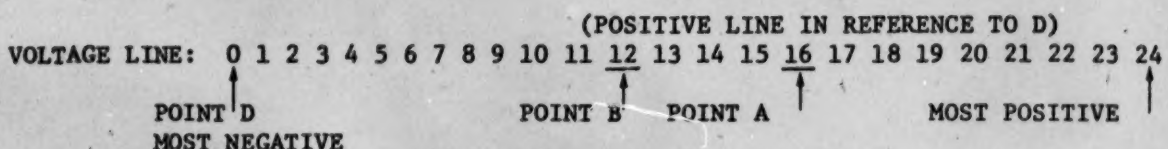
CORRECT RESPONSES TO FRAME 19: 1. 12v, 2. 8v, 3. 4v, 4. 6v, 5. 6v, 6. 12v, 7. 12v, 8. 0v

CORRECT RESPONSES TO FRAME 20: 1. 2 amps, 2. 16v (+), 3. 12v (+), 4. D (+), 5. 4v, 6. Zero (0).

Frame 21

Did you notice the difference between points A and B? You saw that point A was 16 volts positive and point B was 12 volts positive. There is 4 volts difference between the two voltages (16 - 12 = 4). The difference between the two voltages (points A and B) means that the circuit is unbalanced. If you have a difference between two voltages, current will flow if a path is provided. We have established a path between points A and B. Now we have to determine which way the current will flow.

To determine which way current will flow is a simple process. Both voltages are positive in respect to D. One is less positive than the other in respect to D. Study the scale below then read the paragraph.


(POSITIVE LINE IN REFERENCE TO D)
VOLTAGE LINE: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
POINT D
MOST NEGATIVE
POINT B
POINT A
MOST POSITIVE

Voltage Scale

Remember, point D is most negative. It is considered ground and therefore it has zero voltage. The two voltages obtained from frame 20 are (B = 12 volts and A = 16 volts) on the scale. It is apparent that 12 is closer to zero than is 16. Point B is more negative than point A. Furthermore, we know that current flows from a negative to a more positive point; hence, current flows across the bridge from point B to point A.

No Response Required

Frame 22

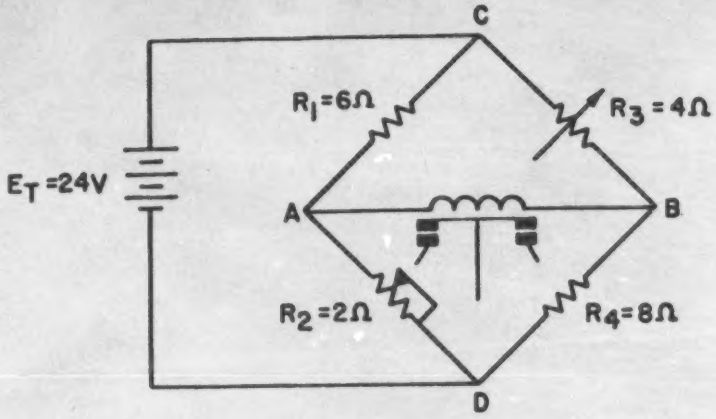


Figure 1.

Refer to figure 1, and answer the following questions on the response sheet.

1. What is the potential at point B in reference to point D? _____ volts (+) (-).

2. What is the potential at point A in reference to point D? _____ volts (+) (-).

3. What is the voltage drop between points A and B? _____ volts.

4. Current will flow across the coil from point ____ to point ___.

5. Which of the two following circuits has the smallest total resistance to current flow? DABC or DBAC?

6. Which of the two following routes will the current flow take: DABC or DBAC?

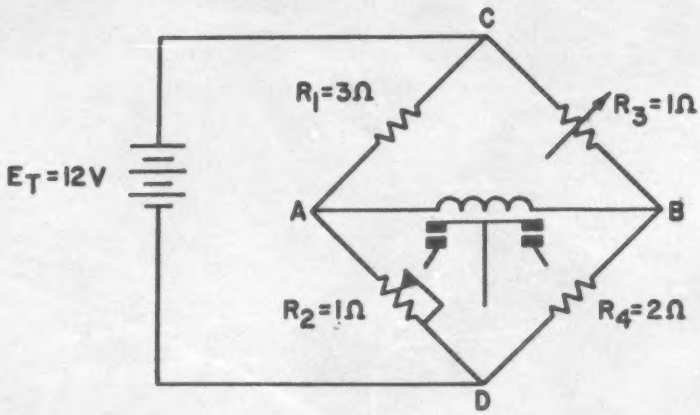


Figure 2.

Refer to figure 2, and answer the following questions on the response sheet.

1. What is the voltage potential at point A in respect to point D?

_____ volts (+) (-).

2. What is the voltage drop across R_2? _____ volts.

3. The voltage potential at point B in respect to D is _____ volts (+) (-).

4. Which way will current flow across the bridge? From _____ to _____.

5. Which of the two following circuits has the smallest total resistance to current flow: DABC or DBAC?

6. Which of the two following routes will the current flow take: DABC or DBAC?

CORRECT RESPONSE TO FRAME 21: No Response Required.

CORRECT RESPONSES TO FRAME 22: Figure 1: 1. 16v+, 2. 6v+, 3. 10v,
4. A to B, 5. DABC, 6. DABC

Figure 2: 1. 3v+, 2. 3v, 3. 8v+,
4. A to B, 5. DABC, 6. DABC.

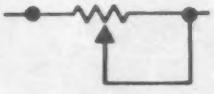
Frame 23

By modifying the DC bridge, it can be used to control aircraft temperatures automatically. Components used in the bridge are listed in the following frames. Fixed resistors have values which do not change. The fixed resistor is used in the bridge circuit to provide a constant resistance value. It can be identified in the schematic by the symbol shown below.

We may desire to adjust the resistance values in a circuit to allow for certain variations or to permit calibration. In this case we would use an ADJUSTABLE resistor. Its symbol is shown here.

Select the adjustable resistor from the electrical display box. Obtain a display box from your instructor. Notice how the wire is wound around the ceramic cylinder and how the wiper contact is moved. Adjustment is accomplished by a specialist using a screwdriver to loosen a small screw. The contact is moved along until it is closer to the end that offers the right amount of resistance. The screw is then retightened.

Identify the symbol in Column A with its name in Column B on the response sheet.

	COLUMN A	COLUMN B
1.		fixed resistor
2.		adjustable resistor

923

CORRECT RESPONSES TO FRAME 23:

1. fixed resistor

2. adjustable resistor

Frame 24

A rheostat is a resistor that has a moveable contact (wiper arm). Moving the contact changes its resistance. The contact is connected to a shaft that is turned by a knob (like the volume control on a radio).

The rheostat is in the bridge circuit to change the resistance on one side of the bridge. This automatically unbalances the circuit.

The pilot manually changes the resistance in the bridge circuit by rotating the rheostat knob. Shown below is the electrical symbol and a picture of the back side of a rheostat. Look in the electrical display box. Note how the resistance may be changed on the rheostat.

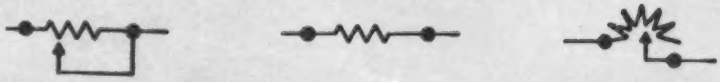
Draw its electrical symbol for each component on the response sheet.

1. _____ Adjustable Resistor.

2. _____ Fixed Resistor.

3. _____ Rheostat.

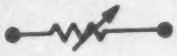
CORRECT RESPONSES TO FRAME 24:



Frame 25

The component that "senses" the temperature of the air is called a temperature sensor. See the illustration below. Find the sensor in the electrical display box. This is one of the more common types in use.

This temperature sensor is a specially designed resistor. Its resistance changes any time the temperature of the air around it changes. The manner in which it changes resistance depends on its "temperature coefficient." That is: if the TEMPERATURE of the air across it increases and the RESISTANCE of the sensor also increases, the sensor has a POSITIVE TEMPERATURE COEFFICIENT OF RESISTANCE. It follows then that with a POSITIVE COEFFICIENT the resistance will decrease if the temperature of the air decreases. The point is, they increase together and decrease together. On the other hand, if the TEMPERATURE increases and the sensor's RESISTANCE decreases at the same time, it has a Negative Coefficient. This also means the sensor's resistance will increase as the temperature decreases. Below is a standard symbol for a sensor. Locate and identify the different types of sensors in the electrical display box.



Complete the statements by using the word increases or decreases on the response sheet.

POSITIVE COEFFICIENT	NEGATIVE COEFFICIENT
1. If temperature increases, the resistance _____.	3. If temperature increases, the resistance _____.
2. If temperature decreases, the resistance _____.	4. If temperature decreases, the resistance _____.

925

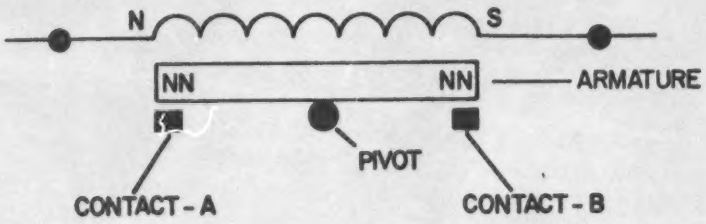
CORRECT RESPONSES TO FRAME 25: 1. increases, 2. decreases,

3. decreases, 4. increases.

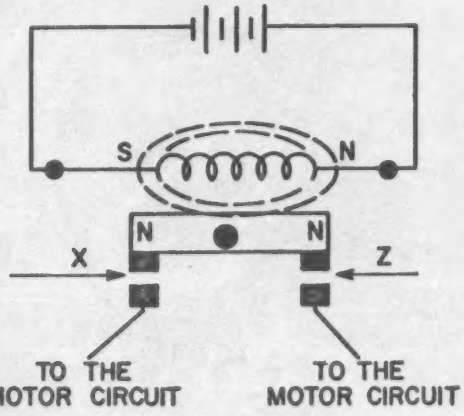
Frame 26

Changing an electrical bridge signal into useful motion, is done by a device called a MICROPOSITIONER. See the picture below. Find the actual component in the display box. Note the contact arrangement.

The micropositioner is a relay that can be tilted like a teeter-totter. It will tilt one way and close one set of contacts, or the opposite way and close a different set of contacts. How it does this can be seen in the simplified explanation that follows.



The armature (see above) of the micropositioner is similar to a magnet that has two north ends. (The south ends being unused.) A coil of wire is running alongside. If current flows through the coil, the coil will have a north and south pole. Remember the Law of Polarity; like poles repel and unlike poles attract. The armature will tilt around the pivot point and close the proper contact depending on the polarity of the coil and of the armature. (See arrows X and Z in the figure below). Since it is actually a relay, it will control a valve motor circuit. Check your understanding of the micropositioner's principle of operation by answering the questions on the response sheet.



1. Like poles (attract) (repel)
2. Unlike poles (attract) (repel)
3. Contact X will (open) (close)
4. Contact Z will (open) (close)

If the battery is reversed;

5. Contact X will (open) (close)
6. Contact Z will (open) (close)

927

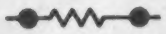
CORRECT RESPONSES TO FRAME 26: 1. repel, 2. attract, 3. open,

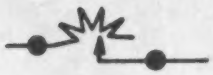
4. close, 5. close, 6. open

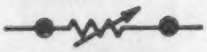
Frame 27

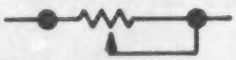
Reversing the direction of current flow through the coil changes the coil's magnetic north and south poles to the opposite ends. The armature tilts to the opposite contact closing a different relay. You will recognize the micropositioner in a diagram by the symbol below. The micropositioner provides a path for current to flow if the bridge is unbalanced.

Identify each symbol by drawing them on the response sheet.

1.  _____

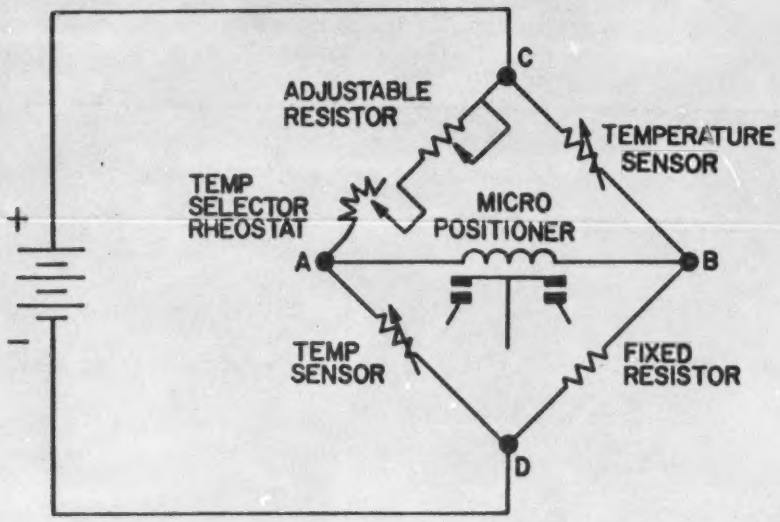
2.  _____

3.  _____

4.  _____

5. _____

The figure below shows all of the components we have mentioned. Now let's go on to learn its operation as a bridge circuit.



You will see that the components are not always found in these positions. All of them may not be used or perhaps, as in some bridges, even more are added. Basically they will however, perform in much the same manner as these. The micropositioner, for instance, may be used in quite another way. We have used it here for one purpose and have already explained its principle of operation in a simplified manner.

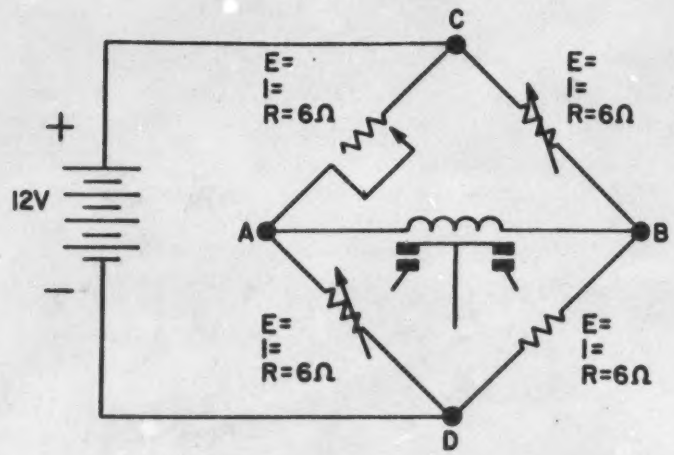
No Response Required

CORRECT RESPONSES TO FRAME 27: 1. Fixed Resistor, 2. Rheostat, 3. Temperature Sensor (or Variable Resistor), 4. Adjustable Resistor, 5. Micropositioner.

CORRECT RESPONSE TO FRAME 28: No Response Required.

Frame 29

Carefully solve the problems in the circuit below. Determine the polarities of points A and B. Use point D as reference.



Complete the following statements on the response sheet.

1. The most negative point in this circuit is (A) (B) (C) (D).
2. The most positive point in this circuit is (A) (B) (C) (D).
3. Point A is _____ volts (+) (-) with respect to point D.
4. Point B is _____ volts (+) (-) with respect to point D.
5. Point A is positive with respect to point B (true) (false).
6. Current will flow from (A to B) (B to A) (neither direction).
7. There is no difference in potential between A and B (true) (false).
8. The bridge is balanced (true) (false).

At this point it is necessary for you to understand the operation of an air conditioning system. Refer to foldout #1. This foldout shows just enough units to permit operation of the system. Air conditioning and completed circuits will be covered in later lessons.

Locate the two engines on the right hand side of the foldout. Remember the text material on Jet Engines? Recall the term engine bleed air? It was stated that the secondary purpose of the compressor section of a jet engine was to provide air for the air conditioning system. Now you will put this knowledge to use.

Locate the arrows coming from both engines. Arrows will indicate the direction of air flow. Follow the arrows from the engines. Notice that the air from both engines combines and enters the hot engine bleed air manifold. The manifold divides into two paths for the air to follow. One path is through the heat exchanger. The other is to the temperature control valve. Let's stop at this point and consider the temperature control valve. This valve has a butterfly-type gate. When open it allows hot engine bleed air to bypass the heat exchanger or closes to prevent bypassing air. Also, it can stop at any point between fully open or fully closed to allow a desired portion of hot air to bypass.

Complete the following sentences on the response sheet.

1. Air which is tapped from the engines is (hot), (warm), (cold).

2. Air is supplied by the _____ section of a jet engine.

3. The temperature control valve allows a portion of the engine bleed air to be _____ around and through the heat exchanger.

931

CORRECT RESPONSES TO FRAME 29: 1. D, 2. C 3. 6(+), 4. 6(+),

5. false, 6. neither direction,

7. true, 8. true.

CORRECT RESPONSES TO FRAME 30: 1. (hot), 2. compressor, 3. bypassed.

Frame 31

Let's assume the temperature control valve is closed. No hot air is allowed to flow through. All the engine bleed air (EBA) is forced to go through the heat exchanger and cooling turbine. Through the combined action of these two units, the EBA temperature is greatly reduced. As a matter of fact, the air will become very cold. Note that airflow coming from the cooling units will go straight into the cabin through the conditioned air vents. At this stage, we are not controlling air temperature, are we? We are merely making the air very cold.

Answer the statements as true (T) or false (F) on the response sheet.

1. Air flowing through the heat exchanger will get hotter.

2. To get cold air to the cockpit, the temperature control valve is closed.

3. To warm up the cockpit we must open the temperature control valve.

Assume that the temperature control valve is fully opened. Air flow, like many other things, tends to follow the path of least resistance. Rather than going through the heat exchanger and cooling turbine, most of the air flows through the open valve. This hot air goes down to the hot and cold mixing section. Then to the conditioned air outlets into the cockpit. Under this condition the cockpit would get extremely hot. The air has bypassed the cooling units through the open temperature control valve. It would be desirable, then, to have a mixture of hot and cold air. This mixture can be obtained by positioning the temperature control valve in a partially open or closed position. Here is where our bridge circuit and micropositioner come into play. By rotating the temperature selector (rheostat) toward cold, we unbalance the bridge. This tilts the micropositioner. An electrical circuit is completed to close the temperature control valve. The pilot then, will receive the cold air he wants, merely by rotating the rheostat.

Refer to foldout 1; answer the following statements on the response sheet.

1. To get a mixture of hot and cold air, the temp control valve should be _____.
2. If the temperature control valve is open, you will receive _____ air in the cockpit.
3. If the temperature control valve is closed, you will receive _____ air in the cockpit.
4. The cooling turbine (cools) (heats) the engine bleed air.

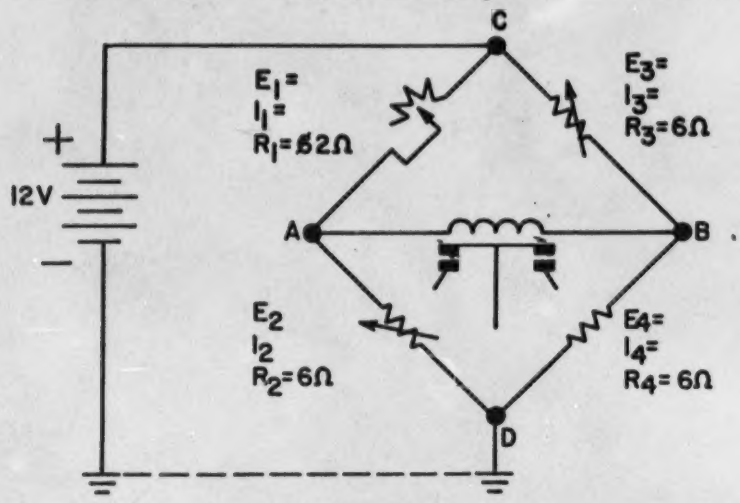
CORRECT RESPONSES TO FRAME 31: 1. F, 2. T, 3. T.

CORRECT RESPONSES TO FRAME 32: 1. partially open or closed. 2. hot 3. cold, 4. cools.

Frame 33

In frame 29 you saw a balanced bridge. Any time the potentials at points A and B are the same, there will be no current flow across the bridge. The coil of the micropositioner will not become magnetized. Therefore, the armature will not tilt either way. Both sets of contacts will stay open.

Refer to the circuit below and foldout 1. Let's see what happens when the temperature selector (rheostat) (R_1) is rotated. As each part is mentioned, locate it on both circuits. Remember that the rheostat is nothing more than a variable resistor. By rotating the rheostat, let us say we have manually decreased the resistance of the rheostat (R_1). You no longer have as much resistance on R_1 as you did in frame 29. As you can see from the circuit below, resistance has been decreased from 6 to 2 ohms. Now you have to recompute the bridge electrical values. After you complete computation, answer the following statements. Remember to use point D as reference.



Write your work on the response sheet.

1. The most negative point of the circuit is (C) (D).
2. Potential at point B is (+) (-) _____ volts.
3. Potential at point A is (+) (-) _____ volts.
4. Which point is most negative? (A) or (B).
5. Which way will current flow across the bridge? (A to B) (B to A).
6. Will the micropositioner tilt in a given direction? (Yes) (No).
7. This bridge circuit is (balanced) (unbalanced).

Refer to foldout 1. Locate resistor R_1 which is the temperature selector (rheostat) (variable resistor). Also locate resistor R_3 which is located in the hot and cold air mixing section. This resistor is a temperature sensing element. The sensing element changes its resistance whenever its temperature changes. Keep these two units in mind as you continue through this lesson.

By changing the resistance of the rheostat R_1 (refer to the figure in frame 33), you unbalanced the bridge circuit. Current flows across the bridge from points B to A. Using the left-hand rule for a coil and D as your reference point, identify the correct responses for the statements on the response sheet.

1. The micropositioner armature (will) (will not) tilt in a given direction.

2. The micropositioner armature (will) (will not) tilt to the (right) (left) (neither direction).

3. The rheostat has its resistance changed (automatically) (manually) (by temperature changes).

4. The temperature sensing elements' resistance is changed (automatically) (manually) (is not changed).

935

CORRECT RESPONSES TO FRAME 33: 1. D, 2. +6v, 3. 9V, 4. B,
5. B to A, 6. Yes, 7. unbalanced.

CORRECT RESPONSES TO FRAME 34: 1. will, 2. will, left,
3. manually, 4. automatically.

Frame 35

Refer to foldout 1. Locate the micropositioner armature. Assume it has tilted to the left. Locate the wire which carries 24V DC to the micropositioner armature. When the armature is tilted to the left, a circuit is completed. 24 volts is sent to the open side of the valve (electrical motor), running it to the open position. As the valve opens it allows more hot air to go to the mixing section. This increases the temperature in the cockpit area. Here is where the temperature sensing element plays a very important role.

Assume that the temperature sensing element has a negative coefficient. (If temperature goes up, the resistance of the element goes down and vise versa). The temperature increase is felt by the sensor as the air flows over it. As the temperature increases, the sensor resistance starts to decrease.

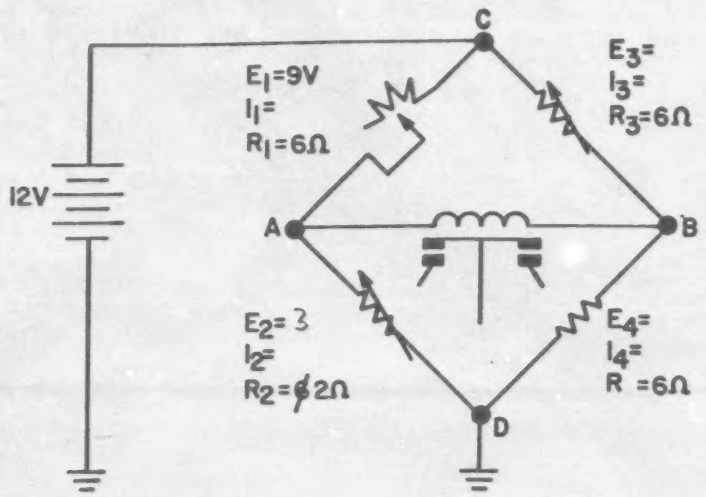
Complete the following statements on your response sheet.

1. The 24V DC applied to the micropositioner armature is the power used to open or close the _____ _____ _____.

2. Current flow from B to A in the bridge would call for _____ air.

3. The temperature control valve is operated by an electric _____.

Refer to the diagram below and foldout 1. Notice that the resistance of R_2 (temperature sensing element) has been decreased from 6 ohms to 2 ohms; this is indicated by the slash mark through the 6. This means that at the start it was 6 ohms (Frame 29) but doe to the rise in temperature, the sensor's resistance has decreased. Recompute the bridge's electrical values. Remember to use point D as your reference.



Complete the following statements on the response sheet.

1. Point A is _____ volts and is (+) (-).

2. Point B is _____ volts and is (+) (-).

3. Current will flow (from A to B) (from B to A) (neither direction).

4. The bridge is (balanced) (unbalanced).

5. The micropositioner armature is (tilted to left) (tilted to right) (not tilted).

This means the cabin air is increasing and this hot air flowing over (touching) R_2 in the cabin (refer to foldout 1) is driving the resistance down in R_2. This has lowered the resistance now causing current to flow from A to B the micropositioner will now begin to brake contact on the left side, which is to the open side of the temperature control valve.

937

CORRECT RESPONSES TO FRAME 35: 1. Temperature control valve

2. hot , 3. motor.

CORRECT RESPONSES TO FRAME 36: 1. 3v, (+) 2. 6V, (+)

3. A to B

4. unbalanced 5. tilted to right

Frame 37

Starting at frame 32, we manually unbalanced the bridge by rotating the temperature selector rheostat. By changing its resistance, we caused current to flow across the bridge from points A to B. This energized a motor circuit to allow a decrease in the temperature of the air entering the cockpit area.

Cooler air begins to flow across the temperature sensing element. The sensors resistance starts to increase. At that point the bridge starts to rebalance. That is, as soon as the sensors resistance again equaled the resistance of the rheostats new setting, current ceased to flow across the bridge.

With no current flowing across the bridge, the micropositioner deenergizes. Current ceases to flow through the motor circuit. When the circuit has balanced and the motor stops running, the system is said to be at its temperature control point.

It must be made clear that at times the temperature sensing element tends to overcorrect itself. Instead of stopping when the voltages are equal (at points A & B) the sensors resistance will continue to decrease or increase after the mixed air temperature has reached the temperature control point. This is due to a slight heat transfer lag between the air and sensor metal. This causes the sensor to be a little late in sending its final "balanced" signal to the bridge. The motor is late in shutting off and overruns. This causes the bridge to unbalance in the opposite direction. The bridge tries to "hunt" for its balanced condition. In other lessons you will study units which are put into the circuit to compensate for this problem. Remember the rheostat and the sensing elements are the units that unbalance and balance the bridge circuit.

Operating changes of the engines or air cooling units frequently change the temperature of the mixed air flowing past the temperature sensing element and into the cabin. When this happens the resistance of the sensor immediately changes, thereby, unbalancing the bridge. The bridge circuit will react to this in the same way as it does when the pilot turns the rheostat knob. Current will flow from A to B or from B to A. This causes the micropositoner to send the proper correction signal to the temperature control valve. This valve, in turn, opens or closes as required to restore the mixed air temperature to the temperature the rheostat is set for.

Complete the following statements on the response sheet.

1. When the bridge is balanced, the system is at its _____ _____ _____.

2. An inaccurate temperature sensor could change the _____ _____ _____.

3. When the bridge is unbalanced, current (will) (will not) flow across the bridge.

4. Whenever the resistance of the sensor differs from the resistance the rheostat is set on, the bridge will not rest until the two resistances are _____.

939

CORRECT RESPONSES TO FRAME 37: 1. temperature control point

2. temperature control point

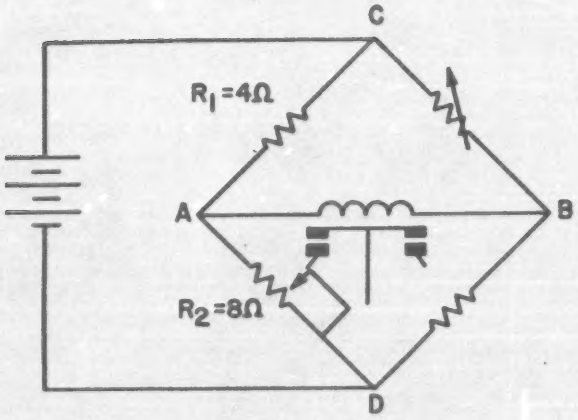
3. will 4. alike

Frame 38

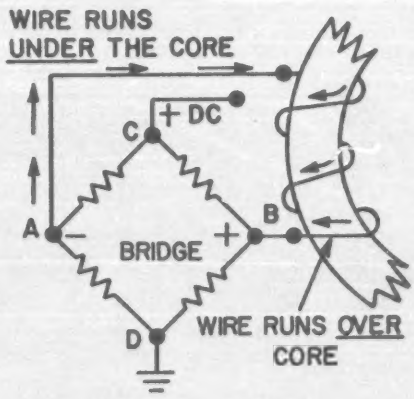
Refer to page 49. If the pilot wants colder air in the cockpit, all he needs to do is to increase the rheostats resistance. This will unbalance the circuit. Current will flow from points A to B, tilting the micropositioner armature to the right. 24V DC will flow to the close side of the temperature control valve.

By partially closing the valve, a greater portion of the air will be routed through the heat exchanger and cooling turbine. A greater proportion of cold air will be delivered to the cockpit.

The micropositioner connecting A to B on the preceding diagrams are not always built the same way. The wiring connections can be made on the outside of the circuit (figure B). Notice that point A is marked a negative potential (less positive). Point B is positive. Following the arrows (- to +) you will note that current flows from A to B on the outside of the diamond. Shown below are both types of circuits. Figure A shows wiring on the inside of the diamond. Figure B shows the wiring connections on the outside of the diamond.



A



B

NO RESPONSE REQUIRED

Complete the statements on the response sheet. If any of your responses are incorrect, review the appropriate frames to determine the correct response.

1. Increasing or decreasing one or more of the resistances will cause the bridge to become unbalanced. (True) (False)

2. A sensor may have a _____ or a _____ temperature coefficient.

3. A resistor that increases its resistance as the temperature around it increases has a _____ temperature coefficient.

941

CORRECT RESPONSES TO FRAME 38: No Response Required.

CORRECT RESPONSES TO FRAME 39: 1. true 2. positive or negative

3. positive

Frame 40

As a final review of your ability to associate symbols and statements, draw the component symbol where the name of the component would normally fit on the response sheet.

1. A fixed _____ has a value that normally does not change.

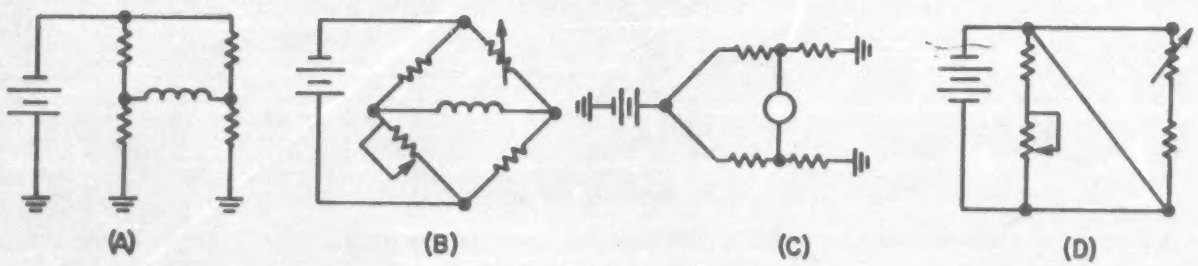
2. Temperature is "sensed" by a _____ _____.

3. The pilot's temperature selector _____ is turned by a knob.

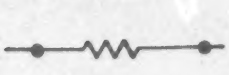
4. A change in the direction of current across a bridge circuit can be sensed by a _____.

5. Small adjustments can be made to a/an _____ with a screwdriver.

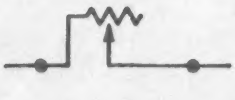
6. Which of these is not really a bridge circuit?

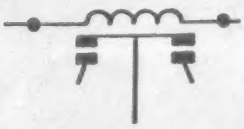


CORRECT RESPONSES TO FRAME 40:

1 

2

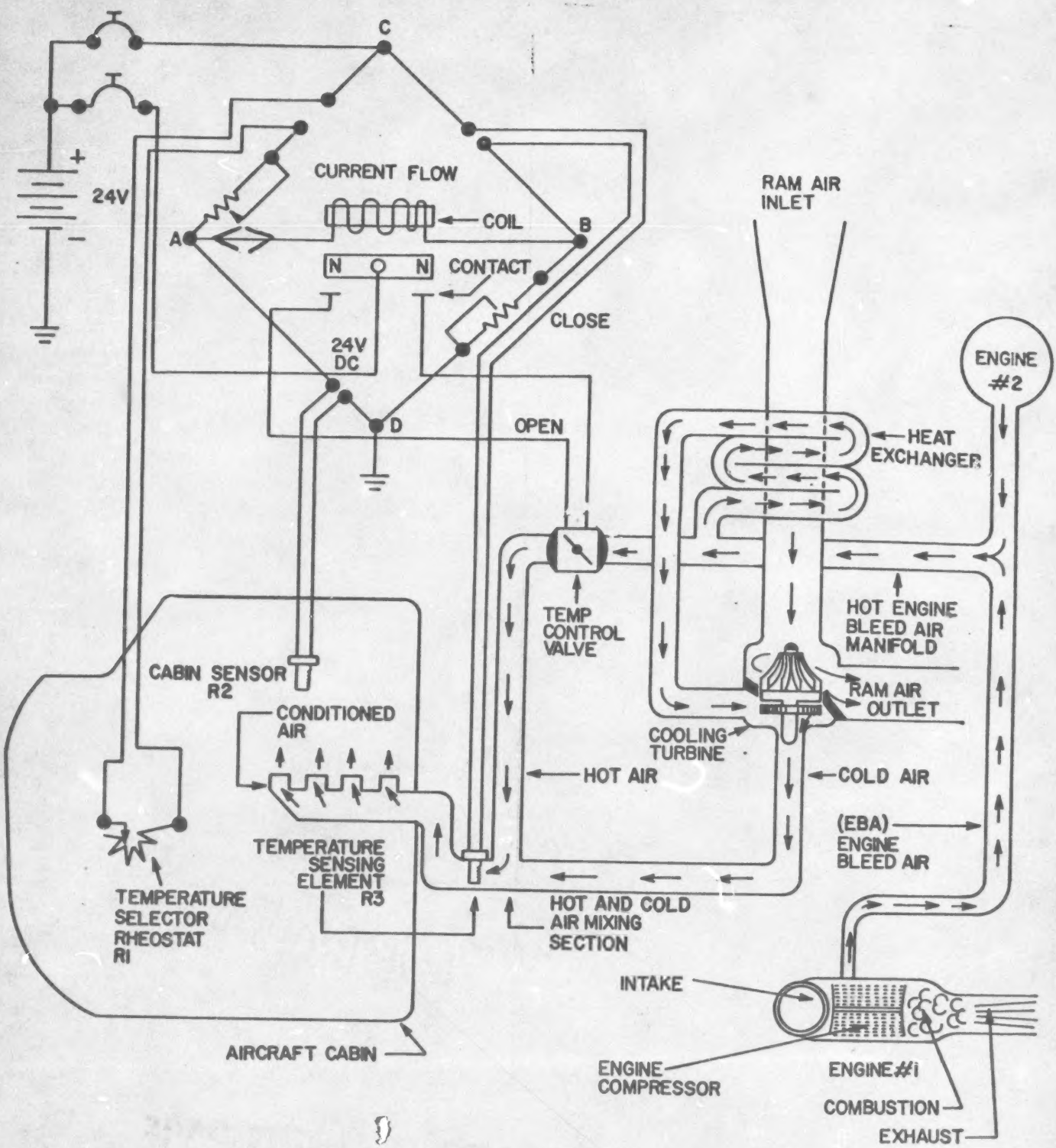
3 

4 

5

6 (D)

END OF TEXT



Foldout 1. Balanced Bridge.

71-16100

WORKBOOK
3ABR42331-WB-122

Technical Training

Aircraft Environmental Systems Mechanic

TEMPERATURE CONTROL CIRCUITS WIRING DIAGRAM

7 August 1979

CHANUTE TECHNICAL TRAINING CENTER (ATC)
3370 Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE
DO NOT USE ON THE JOB

945

Environmental Pneudraulic Branch
Chanute AFB, Illinois

TEMPERATURE CONTROL CIRCUITS WIRING DIAGRAM

OBJECTIVE

After completing this workbook, you will be able to use an electrical diagram, identify a minimum of 8 out of 10 circuit malfunctions, when given the cuase and circuit condition.

EQUIPMENT

	Basis of Issue
Colored Pencils	1 set/student
WB-116A	1/student

PROCEDURE

When you have acquired the above listed equipment, proceed according to the instructions for each project of the workbook. DO NOT change the color of the pencil you are using to trace each part of the circuit unless you are told to do so.

Project 1

In this project you will be tracing out three (3) different circuits, all controlling the same motor and valve assembly (only one circuit will be on at a time). One circuit will "automatically" control the temperature control valve. One circuit will "Manually open" or close the temperature control valve assembly.

The MANUAL HOT & COLD circuits are used as a "back up" system in case the "automatic" circuit malfunctions.

INSTRUCTIONS

Using foldout 1 from the back of the text and a set of colored pencils, trace the circuits in each of the following situations. Locate the various components that you will be working with; ie., the power bus, circuit fuse, temperature control switch, hot and cold relays, micro-positioner, and the temperature control valve. Fro ease of following the circuits, we will trace from the voltage source to ground, although in the actual circuit the current will flow from ground (-) to the voltage source (+).

Supersedes 3 ABR42331-WB-112, 31 October 1978.
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3370TCHTG/TTGU-P - 300; TTV%A - 1

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1. Using a red pencil, trace the following voltage source.

a. Trace from the 28V DC power bus along wire H28A18 to the five amp fuse, through this fuse along wire H29A18 to the temperature control switch. Stop at this point for a moment.

Note: This temperature control switch provides power to operate the AUTOMATIC, MANUAL COLD, and the MANUAL HOT circuits. To operate any of the three circuits from this point it is necessary to position the "switch" to the position that is desired. From the switch you will be using three different colors of pencil to show you the distinct separation of the three circuits even though they all control the same valve assembly.

If the power circuit you have just traced does not look like the completed portion of figure one, redo the previous step 1 or ask your instructor for assistance.

2. Using a green pencil place the temperature control switch to the "manual cold" position and trace the following voltage source.

a. Trace along wire H31A18 over to junction A2 of the "cold relay," from A2 along wire H31B18 through the close field winding of the temperature control valve, to junction "A" of the valve assembly. The symbol ( ) represents the motors armature field, brushes or slip rings and end frame. Next trace from junction A to the motor, then from the motor along wire NMA18 to the ground point ( ).

(1) From your previous study of DC motors you should recall that if you apply voltage to the close field and armature windings of the valve, the armature and valve shaft begins to rotate, in turn rotating a unit or butterfly device of some type to a "closed" position.

(2) From the previous study of bridges you learned how the position of this temperature control valve butterfly affected the cockpit temperature. If you do not recall how this valve mixes the ratio of hot and cold air, then refer back to the text prior to this one that covers the bridge's operation in relation to the temperature control valve.

The manual cold circuit you have just traced, should look like the completed portion of figure 2. If not, redo step 2, or ask your instructor for assistance.

3. Using an orange pencil, trace the voltage source for the manual hot position.

a. Trace across the temperature control switch to the "hot" position along wire H30A18 to junction A2 of the hot relay. Now trace from junction A2 along wire H30B18 through the OPEN FIELD winding of the motor to junction A. Then trace on to the ground point, along the motor ground wire NMA18.

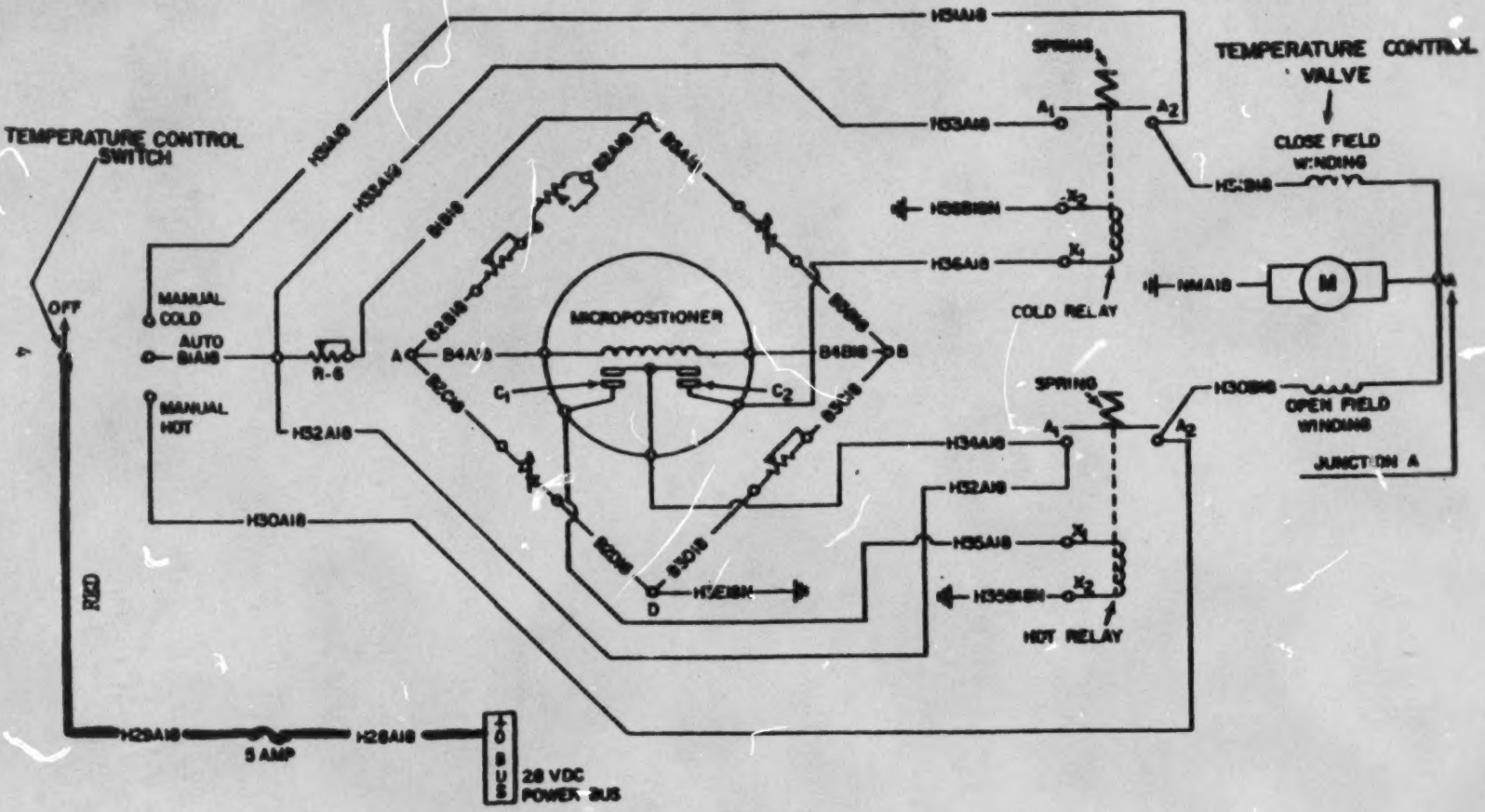
TEMPERATURE CONTROL SWITCH
OFF
MANUAL COLD
AUTO
MANUAL HOT
R-6
MICROPOSITIONER
A
B
C1
C2
D
TEMPERATURE CONTROL VALVE
CLOSE FIELD WINDING
OPEN FIELD WINDING
JUNCTION A
COLD RELAY
HOT RELAY
SPRING
M
5 AMP
28 VDC POWER BUS

Figure 1.

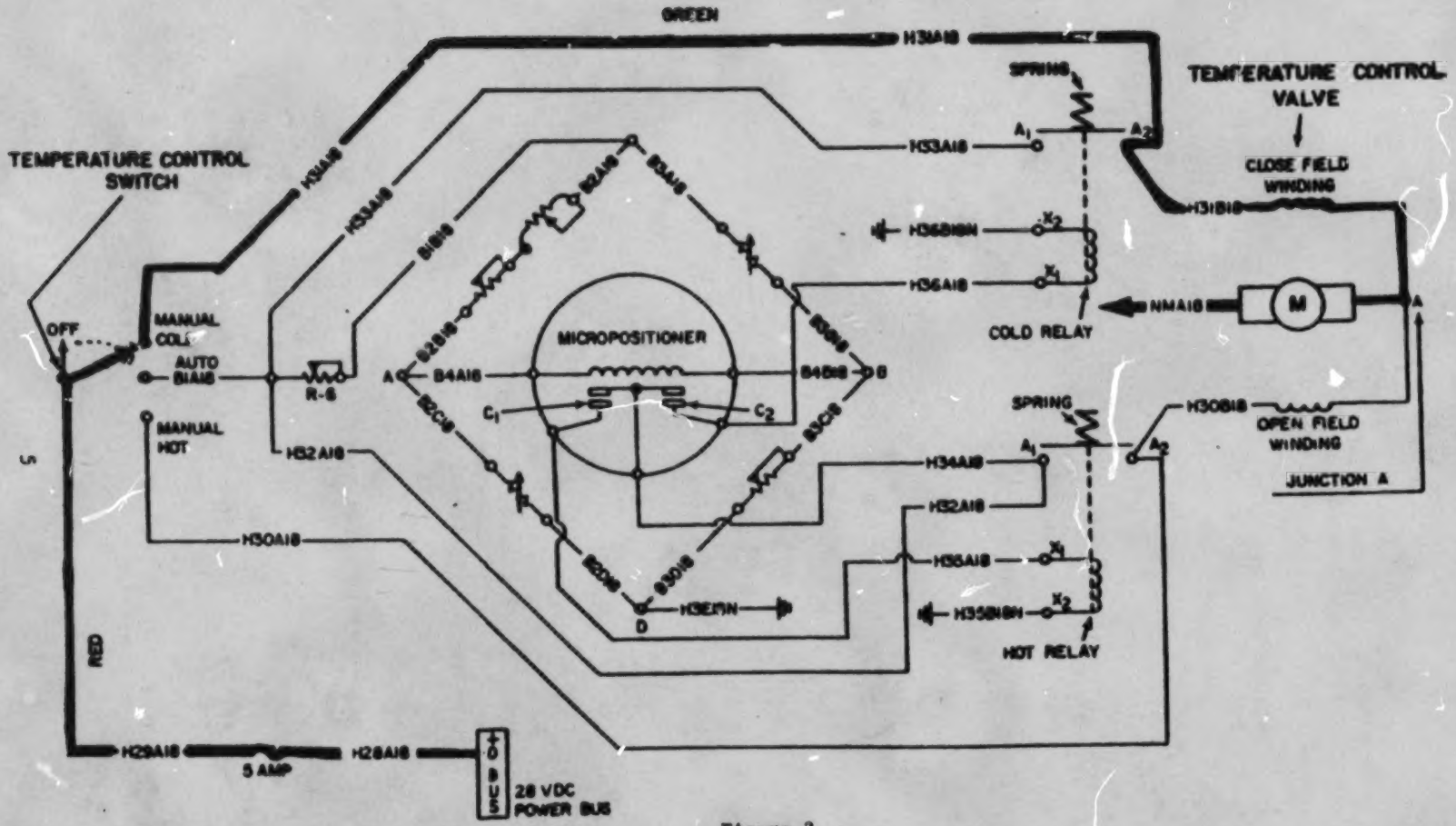
GREEN
H31A18
SPRING
TEMPERATURE CONTROL VALVE
TEMPERATURE CONTROL SWITCH
H33A18
CLOSE FIELD WINDING
H31B18
H35B18N
H36A18
COLD RELAY
NMA18
M
OFF
MANUAL COLD
AUTO BIAS
R-6
MICROPOSITIONER
B4A18
B4B18
C1
C2
MANUAL HOT
H32A18
H34A18
H30B18
OPEN FIELD WINDING
JUNCTION A
H30A18
H35A18
H35B18N
HOT RELAY
H28E18N
RED
H29A18
5 AMP
H28A18
28 VDC POWER BUS

Figure 2.

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(1) At this point the armature rotates and in turn will open the butterfly allowing hot air to enter the cockpit as long as the switch is left in this position.

The manual hot circuit you have just traced should look like the completed portion of figure 3. If not, redo step 3 or ask your instructor for assistance.

(2) From previous lessons you learned that you must get a ratio of hot and cold air to the cabin. In the manual range just explained, there must be a method so that you can momentarily position the temperature control switch to manual hot or cold and position the valve to the desired point where you want it; hot, warm, cool, or cold air.

b. If the switch is properly constructed this can easily be accomplished. Refer to the illustration below, then read the information that follows:

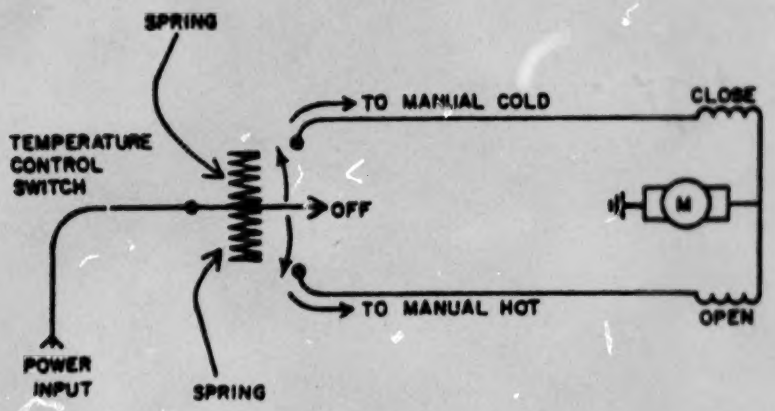

Figure 3.

(1) Note that there are two small springs connected to each side of the switch. If you were to hold the switch to the "manual cold" position and then release it, it in turn would spring back to the OFF position, thus removing power from the close (cold) side of the motor. By the same token if you placed the switch to "manual hot" and then released the switch, it would spring back to the OFF position.

(2) Simply in this manner you could send small blips of power to either side of the motor and position the valve to the exact point desired. Full open, partially open, partially closed or full closed until the desired cockpit temperature is reached.

(a) Due to the varying altitudes and different throttle setting of the aircraft engines, creating temperature changes to the air conditioning system, the temperature would have to be continuously "monitored" in manual to maintain the proper temperatures in the cockpit. For this reason the automatic range was designed to give better temperature control, without having to constantly "monitor" the system.

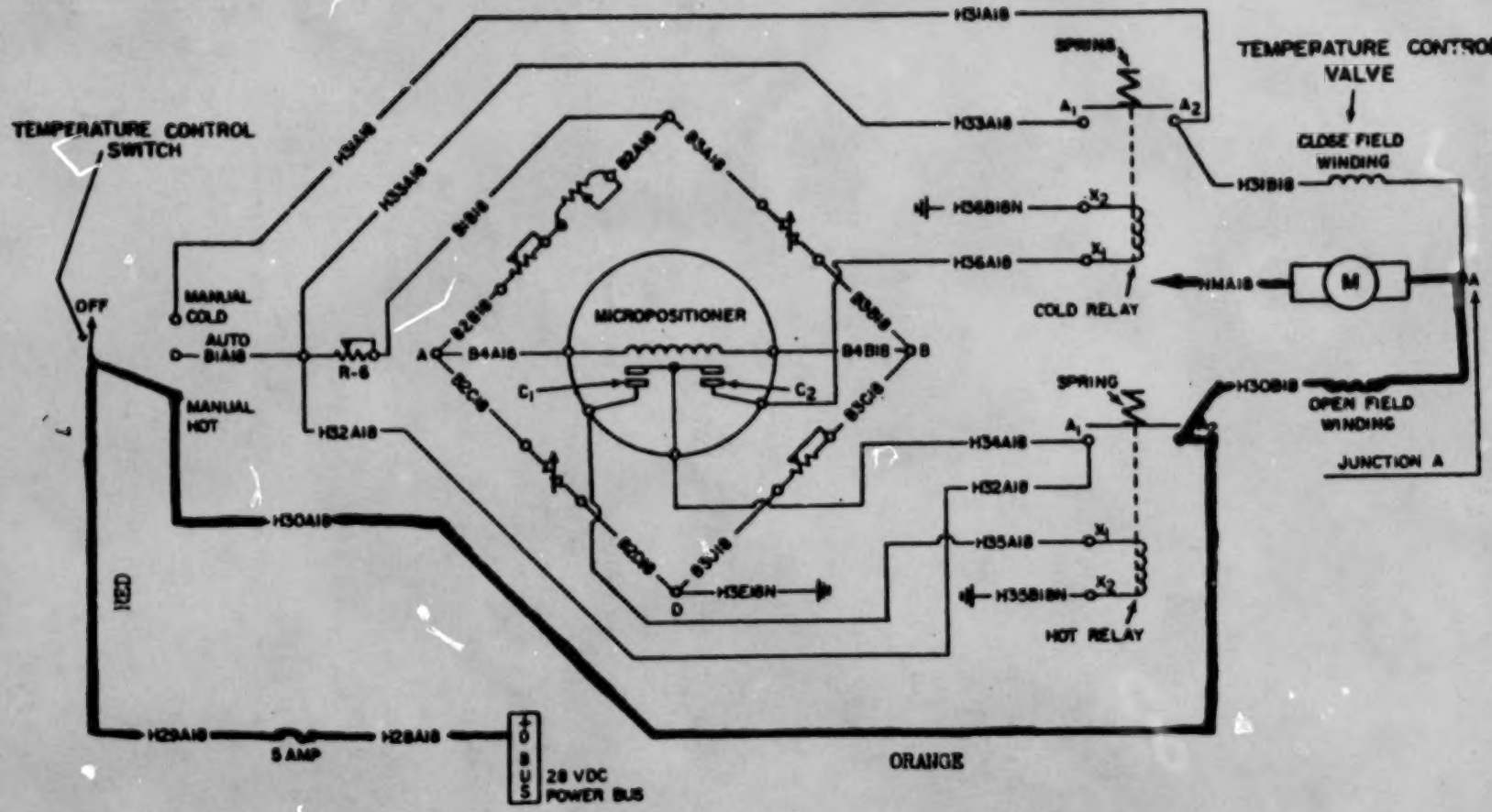
TEMPERATURE CONTROL SWITCH
OFF
MANUAL COLD
AUTO
MANUAL HOT
R-6
MICROPOSITIONER
A
B
C1
C2
D
B4A1B
B4B1B
B2A1B
B2B1B
B2C1B
B3A1B
B3B1B
B3C1B
B5A1B
B5B1B
B5C1B
H31A1B
H33A1B
H34A1B
H32A1B
H30A1B
H29A1B
H28A1B
H5E1BN
H36B1BN
H36A1B
H35A1B
H35B1BN
H34A1B
H32A1B
H30B1B
H31B1B
H1MA1B
SPRING
A1
A2
X1
X2
COLD RELAY
HOT RELAY
TEMPERATURE CONTROL VALVE
CLOSE FIELD WINDING
OPEN FIELD WINDING
JUNCTION A
M
RED
ORANGE
5 AMP
28 VDC POWER BUS

Figure 4.

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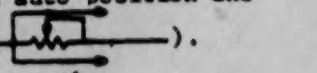
4. Using a blue pencil, trace the following voltage sources in the "auto" position.

a. Draw the temp control switch in the auto position and trace across wire B1A18 to the 3 way junction (). Note at this point the circuit parallels into three paths.

(1) One along wire H33A18 to point A1 of the cold relay.

(2) One along wire H32A18 to A1 of the hot relay, then along wire H34A18 to the micropositioner armature contact.

(3) The other path through resistor R-6 along wire B1B18 to the "top" of the bridge.

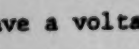
b. Let's take each path individually as you trace them out on the foldout.

(1) First trace along wire H33A18 to point A1 of the cold relay.

(a) Voltage would stop at this point because the cold relay has not been energized at this point. The spring attached to the armature contact is holding it up, therefore breaking the electrical circuit between points A1 to point A2 of the relay.

(2) Now trace along wire H32A18 to A1 of the hot relay.

(a) Again voltage would not be sent across from A1 to A2 of this relay; for at this point it is "deenergized."

(b) Trace from A1 along wire H34A18 to the micropositioner armature contact (). You now have a voltage potential on the contact. At this point with no current flow across the bridge, the contact is in its neutral position and neither relay is energized. Therefore, it should be of special interest to note if there is NO CURRENT across the bridge the system will not energize the hot or cold relays which feed power to the motor windings in automatic.

(3) Now trace across resistor R-6 at the three way junction, along wire B1B18 to the TOP of the bridge circuit.

Note: Resistor R-6 is a voltage dropping resistor to the bridge, simply the aircraft or trainer circuits would only require a small amount of voltage for actual operation. Therefore, this resistor is used to regulate voltage to the bridge.

(a) Notice that the circuit at this point is nothing more than a parallel circuit. One path down the left side, one path down the right side.

Note: At this point you must assume that the bridge is in a balanced condition; that is voltage at points A and B are the same and NO current is flowing across the micro-positioner coil.

(b) Trace along wire B2A18 through the rheostat and variable resistor along wire B2B18 to point A. Continue on wire B2C18 through the temp sensing element (—∿∿—) along wire B2D18 to point D then to the ground point along wire H3E18N.

(c) Go back to the top of the circuit and trace to the right along wire B3A18 through the sensing element (—∿∿—) along wire B3B18 to point B, continue on wire B3C18 through the variable resistor (—∿⊓—) along wire B3D18 to the ground point along wire H3E18N.

The circuit you have just traced should look like figure 5. If your traced circuit does not, redo step 4 or ask your instructor for assistance.

Note: At this point you have traced the manual cold circuit, the manual hot circuit, and the auto circuit under a balanced condition. In the next two steps you will unbalance the circuit and energize each relay in turn, the hot and cold relay circuits.

5. In this step you will create a difference in voltage potential by raising point A's voltage to a higher value than the voltage at point B.

a. This can be accomplished in three ways.

(1) By the rheostat.

(2) By the variable resistor.

(3) By the temperature sensor on the left side of the bridge.

(a) If the rheostat's resistance is decreased, then less voltage would be used to get the current to flow through it; therefore, the voltage at point "A" would be higher. Remember, voltage drop or usage is in proportion to resistance in a series circuit. Simply if a resistor's value changes, the voltage requirement for that resistor or circuit automatically changes.

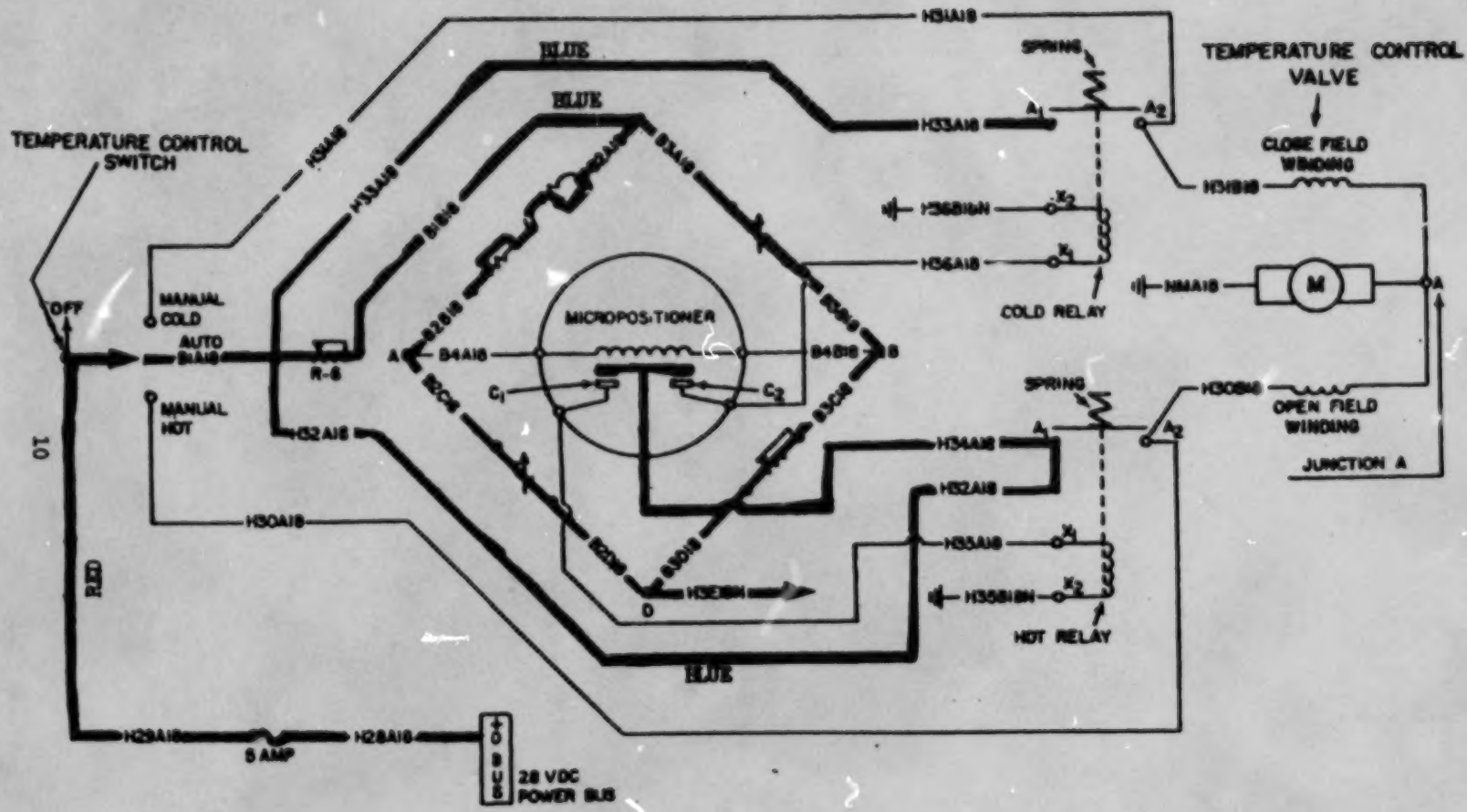

TEMPERATURE CONTROL SWITCH
OFF
MANUAL COLD
AUTO
MANUAL HOT
H1A18
H33A18
BLUE
BLUE
H52A18
H50A18
RED
10
R-6
MICROPOSITIONER
B4A18
B4B18
C1
C2
H34A18
H32A18
H35A18
H35B18N
H36B18N
H36A18
SPRING
COLD RELAY
HOT RELAY
TEMPERATURE CONTROL VALVE
CLOSE FIELD WINDING
H31B18
NMA18
M
OPEN FIELD WINDING
H30B18
JUNCTION A
H29A18
5 AMP
H28A18
28 VDC POWER BUS

Figure 5.

(b) By the same token, the resistance of the variable resistor could be decreased also making a higher voltage for point A due to less voltage being required for it.

(c) On the sensing element, the resistance would have to be increased. By increasing this resistor's value, you would require a larger share of the voltage to get current to flow through it. Therefore, less voltage would be used through the other resistors, in turn impressing a higher voltage across point "A" to the sensing element.

b. Now that a higher voltage has been established at point "A" than point "B", there would be current flow across the bridge.

Note: Always remember that if a resistor's value changes, for any reason, voltage will automatically be changed, either increasing or decreasing the voltage requirement for that unit or units.

(1) Using the orange pencil, again trace across the bridge from point "B" to point "A".

(a) Point B now has a low voltage. Point A has the higher voltage potential. Example: Point B = 6 volts, point A = 8 volts.

(b) From your previous study you should note that the micropositioner coil magnetizes and the armature is offset/tilted to the left. Note the illustration below.

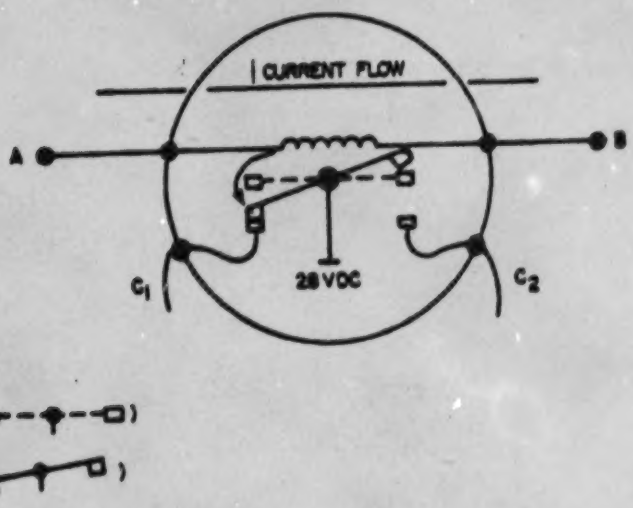


Figure 6.

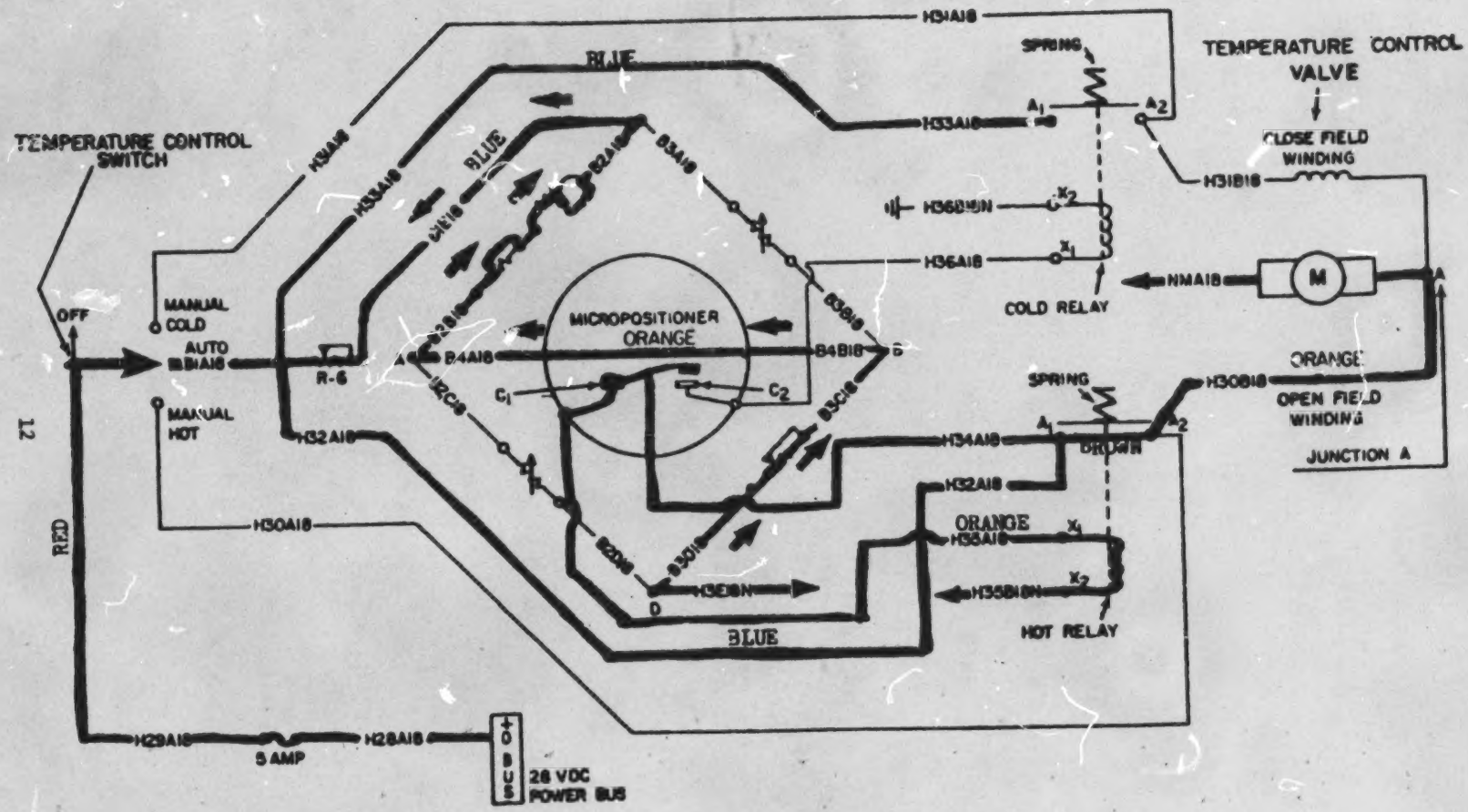

TEMPERATURE CONTROL SWITCH
OFF
MANUAL COLD
AUTO
MANUAL HOT
R-6
H31A18
H33A18
H32A18
H30A18
H29A18
H28A18
5 AMP
+ BUS
28 VDC POWER BUS
RED
12
BLUE
MICROPOSITIONER ORANGE
B1A18
B2A18
B3A18
B4A18
B4B18
B2C18
B3C18
B2D18
B3D18
B3E18N
C1
C2
A
B
C
D
TEMPERATURE CONTROL VALVE
SPRING
A1
A2
CLOSE FIELD WINDING
H31B18
H36B18N
H36A18
X1
X2
COLD RELAY
H44A18
M
ORANGE
H30B18
OPEN FIELD WINDING
JUNCTION A
H34A18
DRIVEN
H35A18
H35B18N
HOT RELAY

Figure 7.

c. Using the orange pencil, trace from C1 to X1 of the hot relay through the coil to X2 to ground along wire H35B18N. The relay now becomes a temporary magnet and pulls the relay contact down, making a path for voltage from A1 to A2 of the hot relay. Use a brown pencil and trace across to A2 then on to the hot motor winding to ground.

Note: At A2 of the hot relay, auto hot and manual hot uses the same wire to get to the motor windings.

The circuit you have just traced should look like figure 7. If not, redo the previous section, or ask your instructor for assistance.

6. In this step, lower the voltage at point A. Assume that this voltage is now lower than point "B".

a. Again this can be done by changing any of the resistance values on the left side of the bridge. This could have easily been done on the right side of the circuit; however, the left side is merely being used as a point of reference.

b. Now that a lower voltage is established at point A, current will flow from A to B (left to right across the bridge).

(1) The micropositioner armature contact tilts/offsets to the right in turn energizing the contact to C2. Note the illustration below. Dotted armature contact indicates <u>balance</u> condition of the bridge.

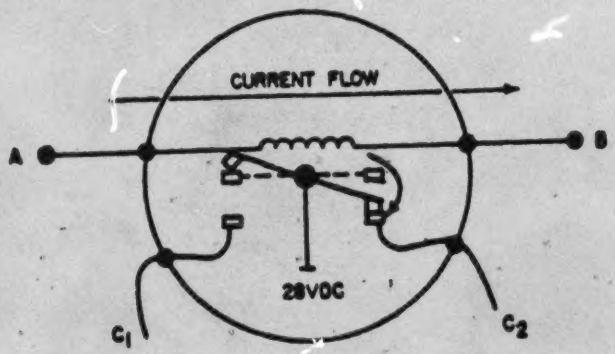


Figure 8.

c. Using a green pencil, trace current from point A across the micropositioner to point B. Trace out contact C2 to X1 of the cold relay through the coil to X2 to ground.

(1) This relay now becomes energized, the contact between A1 and A2 is pulled down and <u>makes</u> the electrical circuit.

d. Trace from A1 (using a brown pencil) to A2 through the close (cold) motor windings to the ground point along wire NMA18.

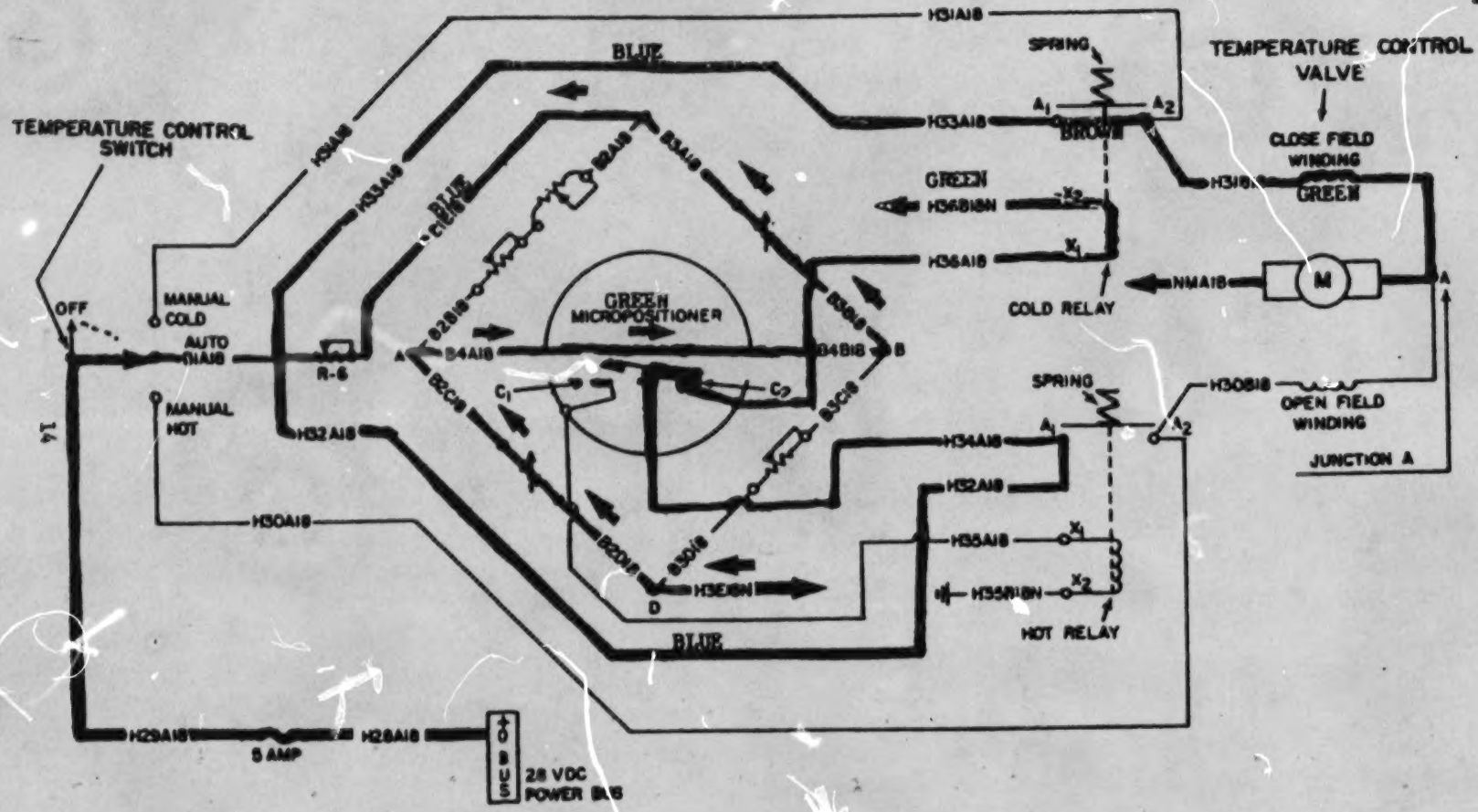

TEMPERATURE CONTROL SWITCH
OFF
MANUAL COLD
AUTO
MANUAL HOT
R-6
H31A18
H33A18
H32A18
H30A18
H29A18
5 AMP
H28A18
+ BUS
28 VDC POWER BUS
BLUE
CLOSE
B2B18
B2A18
B4A18
B4B18
B3A18
B3B18
B2C18
B3C18
B2D18
B3D18
GREEN MICROPOSITIONER
C1
C2
A
B
D
H34A18
H35A18
H35B18N
H36B18N
H36A18
H3E18N
SPRING
A1
A2
BROWN
TEMPERATURE CONTROL VALVE
CLOSE FIELD WINDING
H31B18
GREEN
X2
X1
NM A18
M
COLD RELAY
H30B18
OPEN FIELD WINDING
JUNCTION A
HOT RELAY

Figure 9.

Note at A2 of the cold relay that "auto cold" and "manual cold" use the same wire at this point to transfer voltage to the motor windings.

This completes project 1. The figure you have just traced should look like figure 9. If you do not understand what you have done up to this point and why, then redo this project. If you still do not understand, then notify the instructor for aid.

Project 2

INSTRUCTIONS

Using foldout 2, note the circles and squares with numbers at the various points on the circuit. The circled numbers (③) represent an OPEN wire at this point. The squares (④) indicate that the circuit is SHORTED at this point. REMEMBER! If for "any reason" a resistor's resistance is changed on either side of the circuit, voltages at points A and/or B will be changed.

1. Using the illustrations below, see what happens when either side of the bridge resistance is changed. Illustration 1 indicates a normal circuit under a balanced condition (no current flow across the bridge). Illustration 2 shows the same circuit with resistor R-3 broken (open) and the circuit is shown in an unbalanced state.

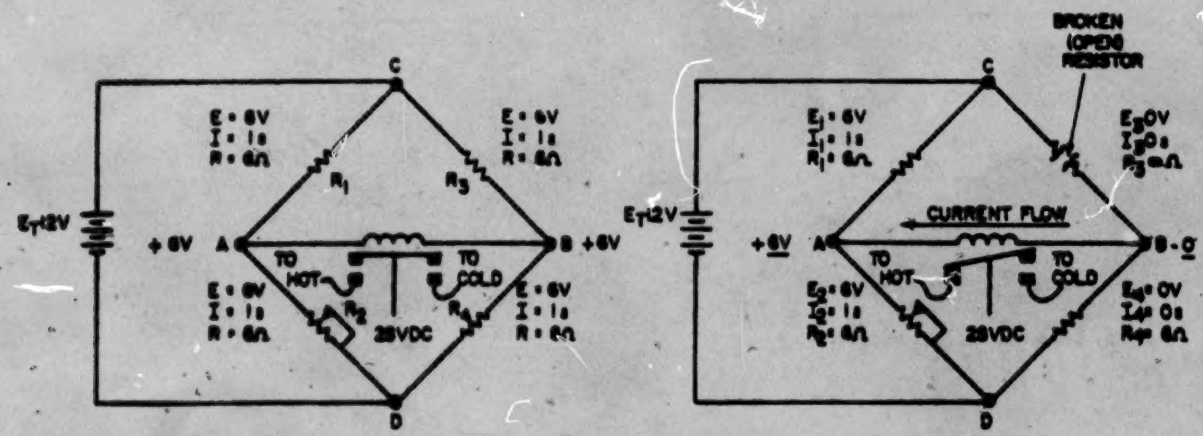


Illustration 1 Illustration 2

Figure 10.

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a. Note that the left side of the bridge in illustration 2 is normal and still has a +6 volt potential at point A. Note further that with R-3 broken, that there is NO voltage across the break and the voltage potential at point B is at a zero (0) volt potential. From your previous studies you know that current would now flow from point B (-) to point A (+). Keep in mind that point B could be 0, 1, 2, 3, 4, 5, 5.9 volts and current would still flow until B reaches the same voltage as point A, then the circuit would be balanced. With current flow from B to A, the micropositioner armature contact will tilt/offset to the left making contact with the wiring going to the hot relay.

(1) It is noteworthy to realize that at this point the resistor will remain broken until the aircraft returns from flight and you, the maintenance man, correct the malfunction.

(2) In turn the system would be demanding FULL HOT in AUTO at all times.

(3) The crew "must now" select the manual override ranges to control temperature.

2. As you may note, computing the different breaks or shorts on the bridge could become quite a math headache. However, there is a method for figuring out exactly which way current will flow when there is a malfunction on the diamond itself. Study the illustrations below as you read the information below them.

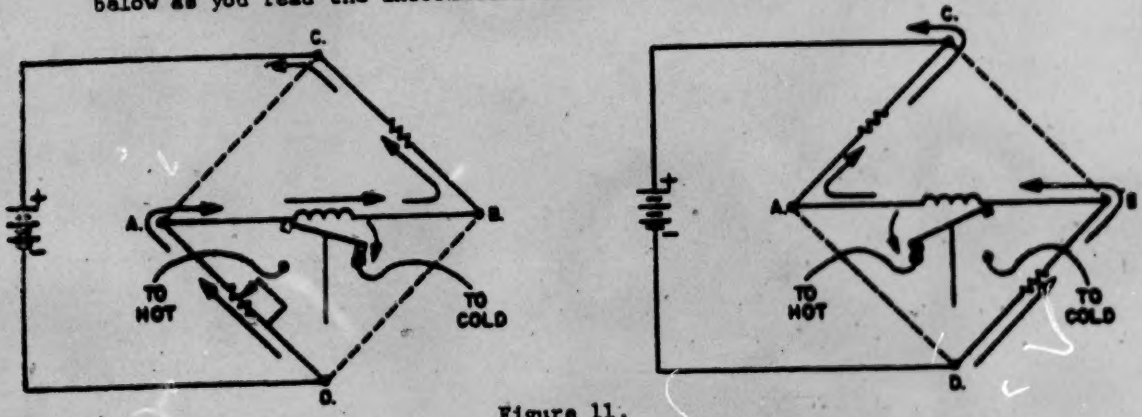

Figure 11.

a. If current were to flow ONLY in a lopsided Z pattern from point D of the circuit (note illustrations 1 and 2) and we used this method, we could readily identify the malfunction and determine which way current would flow across the bridge. Arrows indicate direction of Z, and current flow across the bridge.

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(1) Remember this will only be a method used in aiding you to bypass having to mathematically compute voltages each time there is a short or open on the diamond. Keep these Z from D patterns in your head as you continue.

b. Using the illustration below, let's see exactly how this Z pattern will help in determining which way current will flow on the bridge.

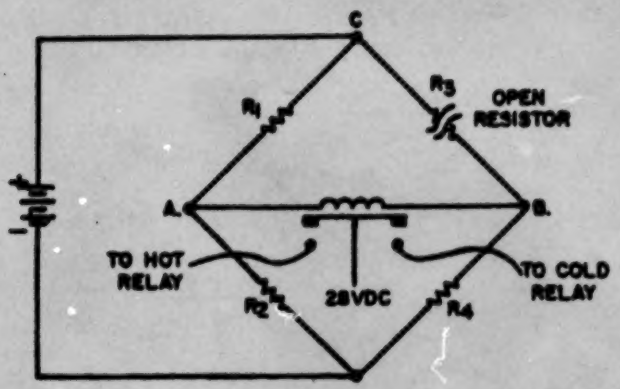

Figure 12.

(1) Using a green pencil and the Z pattern, trace from point D up to point A. So far the circuit looks ok., now trace across from point A to point B then up to the broken path (resistor R-3) of the circuit.

(2) At this point the circuit has an incomplete path and current could not flow on to point C or anywhere. (You must have a complete path for current to flow.) Seeing as how you don't have a complete path from this point to C and on to positive, there is NO ACTION on the micropositioner coil and it remains in the neutral position (neither relay on).

(3) So now you must go back to point D and start the Z pattern in the opposite direction. Use figure 13 shown below, in this procedure.

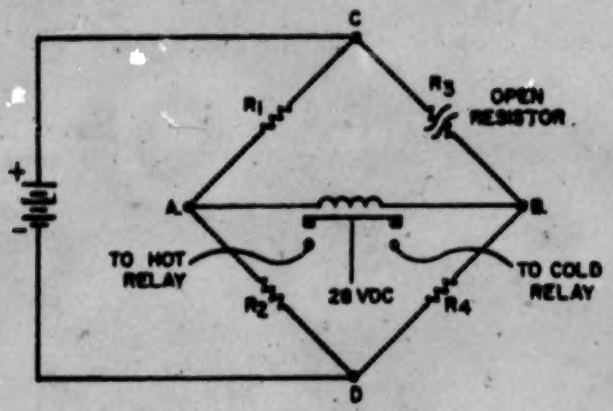

Figure 13.

961

(a) Using a green pencil, trace from D to point B across to point A, up to point C and to the positive bus. As you can see, the circuit is complete; the armature contact is tilted to the left, and the HOT circuit is energized. Trace the contact in its tilted position to the left in orange.

c. What if resistor R1 were shorted in the illustration below? Remember, if the bridge is unbalanced, the current will always take the Z pattern from the lowest voltage potential to the highest. In figure 14 below, use the green pencil to trace out your Z pattern, and then answer the questions about the circuit.

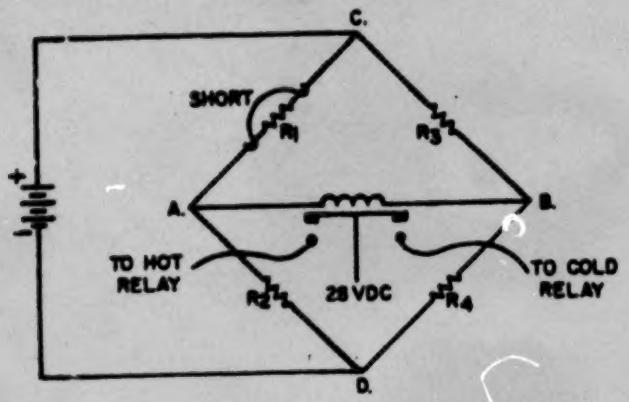

Figure 14.

Answer the following questions.

1. Current now flows across the bridge from _____ to _____. (A to B, B to A)

2. This Z path has the least resistance _____. (DBAC/DABC)

3. The micropositioner contact is (tilted/not tilted) _____ to the (left/right/neither direction) _____.

4. Current flow takes the path with the _____ (least/highest) resistance.

Check the following page for the correct answer to the illustration and questions. If your answers do not agree with these, then reread the information given.

Answers to illustration and questions 1 through 4 on page 18.

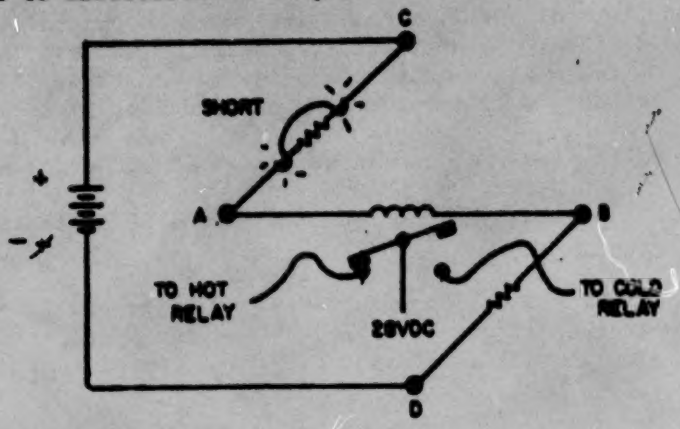

Figure 15.

c. Your circuit should appear as the one above. This is the portion of the circuit that you should have traced in green. From point D to b to A to C. Note the position of the micropositioner armature contact.

1. B to A.

2. DBAC.

3. tilted - left.

4. least.

(1) The system is still demanding full hot as was the previous circuit.

(2) The thing to remember is that current goes in the opposite direction of the opens and flows with the shorts when using the troubleshooting aid of "Z" from D.

d. As was stated previously, this "Z" from D is merely an aid in troubleshooting. If the circuit was to be mathematically computed in each case, you would find that this method proves correct in determining direction of current across the bridge.

Using toldout 2 and figure 16, you will identify circuit malfunction(s) in the temperature control circuit which are caused by OPENS or SHORTS. You will place an "X" in the block which will give you the correct circuit malfunction. The first one has been done for you. Numbers 2, 3, 4 you must do for practice and have them checked by your lab instructor before you progress to the problems in the progress check.

963 First look at figure 16 and find practice problem 1, then using foldout 2, look for problem 1 in the temperature control circuit. After you have found 1 on foldout 2, you will see that it points to an OPEN in the power lead to the temperature control switch. You can identify an open in this foldout 2 by the circle around the number of the cause, or you can also look on figure 16 under the cause column.

1. Figure 16 gives you the answer sheet for practice problem 1.

2. Foldout 2 gives you the location of the OPEN circuit power lead.

3. The circuit condition column for the temperature control switch and rheostat in figure 16 will give you the position the controls will be in during an operational check when the given CAUSE is in the circuit.

a. How will the circuit malfunction when the temperature control switch is in the manual cold position? You're right; 1 is an open in the power circuit causing the power to be cut off to the temperature control switch. By tracing the circuit, you know this switch must have power to it for both the manual and auto circuit to operate or the whole system will fail. This can now be marked in figure 16 with an "X" under (NO OPERATION).

Remember, NO OPERATION means that the temperature control valve will not operate in manual hot, cold or automatic. This does not mean that the bridge will not control the micropositioner and the hot and cold relay.

The selection made is the CIRCUIT MALFUNCTION (NO OPERATION). This is the only complete and correct answer because the power has been cut off to the circuits. The above circuit malfunction will result regardless of the temperture control switch and rheostat position.

If you would have selected any of the other circuit malfunctions, your answer may be either half or all wrong.

Note: Be very CAREFUL in selection of the circuit malfunctions. They must describe exactly what is malfunctioning, nothing more or less. Also, always note the position of the temperature control switch and rheostat given in the circuit condition column in figure 16. Sometimes more than one answer could be correct.

PRACTICE PROBLEMS

First look at figure 16 and find practice problems 2, 3, and 4, and then using foldout 2, look for problems 2, 3, and 4 in the temperature control circuit. After you have found 2, 3, and 4 on foldout 2, select the correct circuit malfunction given at the top of figure 16 by placing an "X" in the correct block. Your instructor will grade your work and initial it if you are to progress to the next five problems.

PROGRESS CHECK

The next ten problems will not be done any place but in the classroom and under supervision of the instructor. You will not do these problems in the barracks or at home. You must identify a minimum of 8 out of 10 circuit malfunctions correctly. Your instructor must check your work after the first five problems. If your instructor says your work is satisfactory, the instructor will initial your work allowing you to progress. If the instructor says your work is unsatisfactory, it will not be initialed and you will follow the instructions of the instructor.

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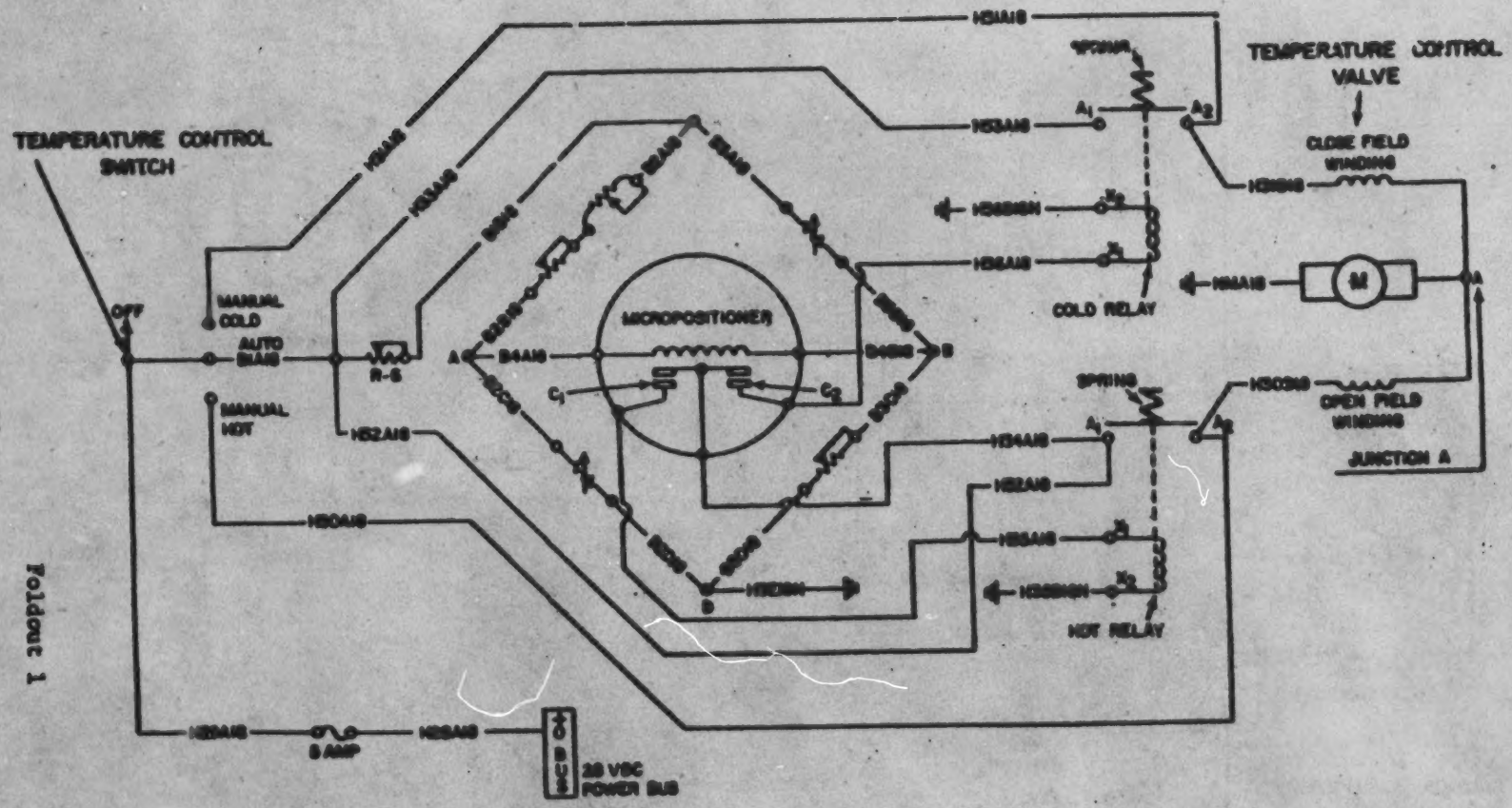
Student complete the following (print).

STUDENT NAME _____
(Last) (First)

DATE PROGRESS CHECK STARTED _____

CIRCUIT CONDITION					CAUSE	CIRCUIT MALFUNCTION(S)								
TEMPERATURE CONTROL SWITCH			RHEOSTAT			No Manual Cold	No Manual Hot	No Auto Cold	No Auto Hot	Full Auto Cold	Full Auto Hot	No Operation	No Auto	Number on Foldout 2
MANUAL COLD	MANUAL HOT	AUTO	HOT (or)	COLD										
X	X	X	X	X	OPEN							X		1
X					OPEN									2
		X	X	X	SHORT									3
		X	X	X	OPEN									4
INSTRUCTOR MUST INITIAL BEFORE STUDENT IS TO PROGRESS →														
X	X	X	X	X	OPEN									5
		X	X	X	OPEN									6
		X	X	X	OPEN									7
		X	X	X	OPEN									8
		X	X	X	OPEN									9
INSTRUCTOR MUST INITIAL BEFORE STUDENT IS TO PROGRESS →														
		X	X	X	OPEN									10
	X				OPEN									11
		X	X	X	SHORT									12
		X	X	X	SHORT									13
		X	X	X	OPEN									14
INSTRUCTOR MUST INITIAL BEFORE STUDENT IS TO PROGRESS →														

Figure 16.



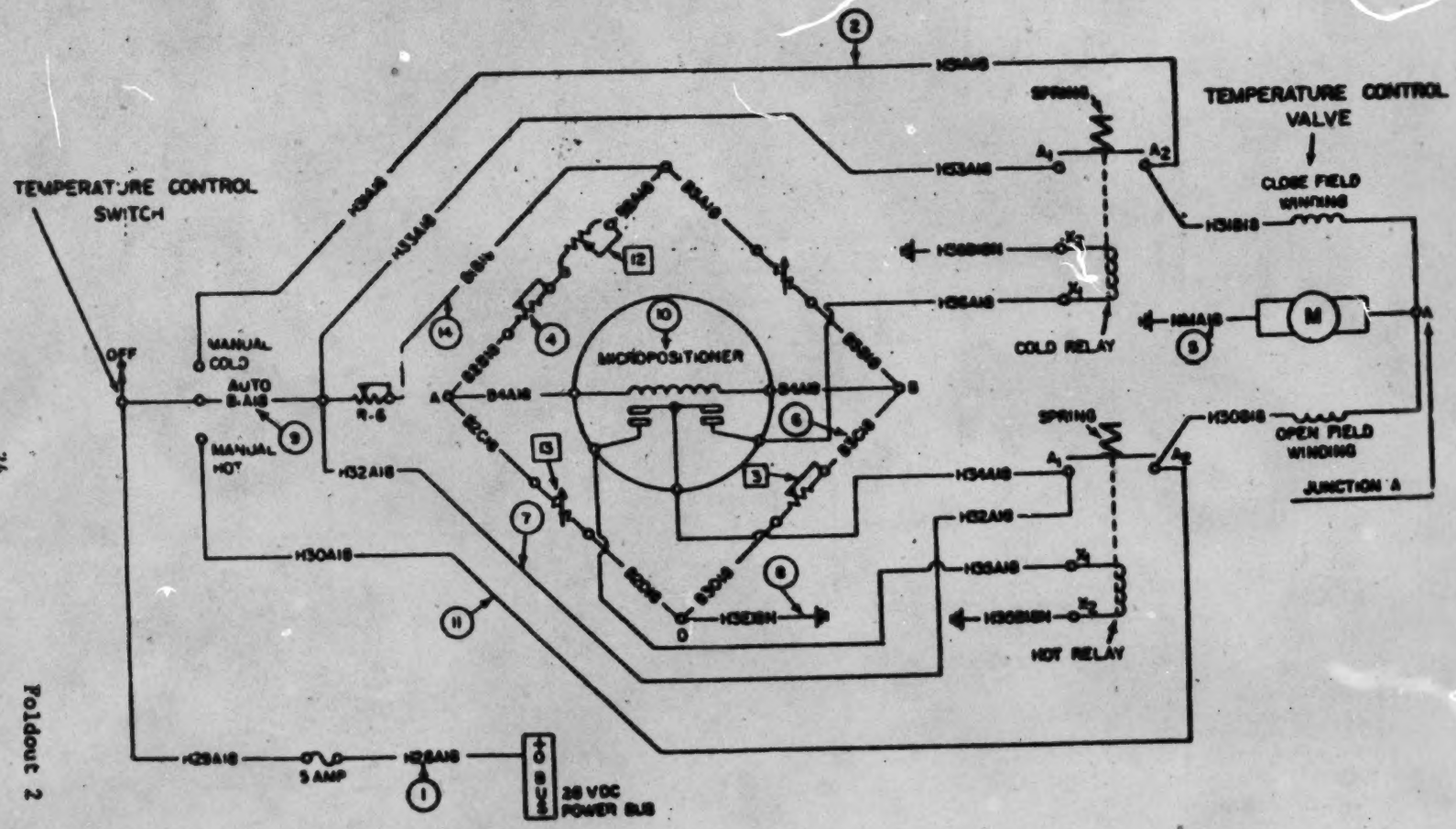
Foldout 1

23

985

986

996


TEMPERATURE CONTROL SWITCH
OFF
MANUAL COLD
AUTO
MANUAL HOT
R-6
MICROPOSITIONER
TEMPERATURE CONTROL VALVE
CLOSE FIELD WINDING
OPEN FIELD WINDING
COLD RELAY
HOT RELAY
SPRING
JUNCTION A
5 AMP
28 VDC POWER BUS

Foldout 2

WORKBOOK

3ABR42331-VB-122A

Technical Training

Aircraft Environmental Systems Mechanic

TEMPERATUE CONTROL CIRCUITS TROUBLESHOOTING

31 October 1978

CHANUTE TECHNICAL TRAINING CENTER (ATC)
3370 Technical Training Group
Chanute Air Force Base, Illinois

Designed for ATC Course Use.

Do Not Use on the Job

ATC FORM 214 (JAN 76) OBSOLETES ATC FORMS 214, MAY 69, 522, NOV 63 AND 523, MAY 71. STANDARD COVERSHEET

969

Environmental Pneudraulic Branch
Chanute AFB, Illinois

3ABR42331-WB-122A

TEMPERATURE CONTROL CIRCUITS TROUBLESHOOTING

OBJECTIVES

After completing this workbook, you will be able to:

Use a temperature control circuit, electrical diagrams, and multimeter, locate and record a minimum of 4 of the 5 trouble causes.

EQUIPMENT

	Basis of Issue
Multimeter	1/student
DC Bridge Trainer #3072	1/student

PROCEDURE

When you have acquired the above listed equipment, proceed according to the instructions for each project of the workbook.

When you leave your trainer for scheduled or unscheduled breaks insure the following are done before you go.

1. Place the control switch to OFF position.

2. Secure your multimeter during this period.

   a. Insure the controls on the meter are properly set for storage.

   b. Leave the test leads attached to the meter.

   c. Wrap the meter leads attached to the meter.

   d. Place the meter on the locker shelf.

3. When you return from the break take the same meter and go back to work.

Supersedes 3ABR42331-WB-115A, 5 April 1977.
OPR: 3370 TCHTG
DISTRIBUTION: X
3370 TCHTG/TTGU-P - 300; TTVSA - 1

990

Project 1

1. This project is performed in the electrical laboratory. Report to the lab instructor with this workbook and your progress record. Here you will learn the operation and troubleshooting techniques required to successfully check out this circuit. BE SURE TO REMOVE YOUR JEWELRY WHILE IN THE LAB AREA.

Note: You must acquire a multimeter from the lab instructor, upon receipt and sign out of the meter. The instructor will direct you to the trainer that you will be operating.

a. Open the multimeter and place it at the top of the trainer in the holder that is provided.

b. Remove the test leads and probes from the meter cover and insert them into the proper holes in the meter jacks. (Red to Red - Black to Black.)

c. Position the "Function" switch to OHMS Range X 10.

d. Zero the ohmmeter. If it does not zero notify the instructor.

e. Put the test leads aside for the present so that you get a clear view of the trainer.

2. Before you can effectively troubleshoot any system you must become thoroughly familiar with the "normal" operation of the system. An "operational check" of the system MUST BE performed prior to trouble-shooting, to determine the condition of the system and to help you to locate exactly which part of the circuit is defective.

3. Follow the procedures below and perform an operational check of the system.

a. Note the physical location of the 28V DC bus, fuse, temperature control switch, micropositioner, hot and cold relays and the temperature control valve and the different ground points (⏚) on the circuits. These ground points/symbols actually means that the negative wire, of a given component, is connected to the fuselage/frame of the aircraft in some manner. On the trainer you will note at the very bottom of the bridge, a small round plastic hole that says ground. This hole (ground) represents the fuselage of the aircraft. Therefore, if you take a meter reading on a negative wire it will be taken from the negative side of the component to the frame/fuselage which is referred to as the <u>common</u> ground.

b. Place all the trouble switches on the rear of the trainer to the "off" position.

c. Insure that the trainer is plugged in, this supplies 28V DC to the + bus.

d. Insure that the tie point jacks are installed at points A & B of the circuit. These are two metal rectangles that have 3 nuts and jacks on each plate.

(1) Note the green plastic plate over the close (cold) winding of the motor.

(2) Note the red plastic plate over the open (hot) winding of the motor.

(a) When either light is on (plates have lights behind them) it simulates actual operation of the temperature control valve.

(3) Note the green and red plastic plates across points A and B.

(a) If the red light is on it indicates current flow from B to A, but does not indicate the motor valve has operated.

(b) If the green light is on it indicates current flow from A to B, but does not indicate the motor valve has operated.

Note: As you perform each of the following steps, fill in the information in the blanks provided that correctly identifies correct bridge current or motor operation.

e. Place the temperature control switch to the MANUAL COLD position.

(1) The temperature control valve _____ (opened/closed).

(2) The _____ (hot relay/cold relay/neither relay) energized.

f. Place the temperature control switch to the MANUAL HOT position.

(1) The temperature control valve _____ (opened/closed).

(2) The _____ (hot relay/cold relay/neither relay) energized.

g. Place the temperature control switch to the AUTO position.

(1) If any lights are on, locate and turn resistor R-1's knob either clockwise or counterclockwise until all lights are off. Resistor R-1 is located on the upper left side of the bridge diamond.

Note: Do not adjust any other resistor on the circuit except resistor R-1. If you cannot turn off all the lights while you are in automatic, at this time assure all troubles are off in the rear of the trainer. If this does not solve the problem, inform the instructor so he/she can perform calibration.

h. Now turn R-1 counterclockwise (to the left) until the red light comes on.

(1) There (is/is not) a current flow across the bridge.

(2) This current is from _____ (A to B/B to A/does not flow).

(3) The (hot/cold/neither) relay is energized _____.

(4) The system would be demanding a (cold/hot/no change) _____ temperature for the cabin.

i. Turn R-1 clockwise (to the right) until the circuit is balanced (no lights on). Now continue to turn R-1 clockwise until the green light comes on.

(1) There (is/is not) a current across the bridge _____.

(2) Current flow is from _____ (A to B/B to A/does not flow).

(3) The (hot/cold/neither) _____ relay is energized.

(4) The system would be demanding a (cold/hot/no change) _____ temperature for the cabin.

This completes the operational checkout procedures, now compare your answer with those on the following page. This way you will know that the trainer is operating properly.

Answers to operational check.

e. (1) closed

(2) neither relay

Note that either relay is energized, simply because you are in the "manual" range. Manual bypasses the automatic system completely.

f. (1) opened

(2) neither relay

Note that neither relay is energized, simply because you are in the "manual" range. Manual bypasses the automatic system completely.

h. (1) is

(2) B to A

(3) hot

(4) hot

i. (1) is

(2) A to B

(3) cold

(4) cold

If all your answers agree with the ones given above, and you are THOROUGHLY familiar with the operational checkout procedures, then you are ready to begin with the troubleshooting. If you do not agree with the answers, perform the operational check again, then if you still do not agree contact the instructor for assistance.

4. Use the following meter procedures to checkout the various circuits. Note the different checkpoint locations on the trainer. These are round plastic jacks installed at different points in which the meter leads are inserted to check the circuit at these points.

a. Use the "voltmeter" to check the following circuits.

(1) Power bus to "temp" control switch.

(2) Entire manual <u>cold</u> circuit.

(3) Entire manual <u>hot</u> circuit.

(4) <u>Auto</u> circuit up to "top" or bridge, junction point to A1 of hot and cold relays. From the <u>top</u> of the bridge the diamond will be <u>isolated</u> and checked with the Ohms portion of the multimeter. Do <u>not</u> use your meter at this time.

b. The circuits that you will be checking with the ohmmeter is the diamond, the path across from A to B of the diamond, the ground wires and the hot and cold relay circuits.

5. Turn on switch #1 located on the back of the trainer. You have now placed a trouble into the circuit somewhere.

6. To locate the trouble caused by turning on the trouble switch, ask yourself this question. Which of the circuits, manual hot, manual cold, auto, do not operate as they should? Then proceed in the following sequence.

a. Place the temperature control switch to MANUAL COLD. Note that it works as it should. If you forgot this check then refer back to project 1, para 3, step e.

b. Place the temperature control switch to MANUAL HOT. Note that it operates as it should. Project 1, para 3, step f.

c. Place the temperature control switch to AUTO. Turn R-1 counterclockwise. Note that the bridges fails to respond and does not run the motor to the close position.

d. Turn R-1 clockwise. Note that the bridge still does not respond and you cannot energize the hot relay to run the motor to the open position.

7. Here then is where the actual troubleshooting begins. You have determined that the "manual" circuits are normal and that you have "NO AUTO" operation at all.

a. Note with the manual circuits "good" that there is no reason to check these circuits at this point.

b. You must now locate the trouble in the AUTO range by using the multimeter as a testing device.

(1) The first step is to ground the black meter lead to the common ground. Set the meter up to read 28 volts dc.

c. With the switch in the AUTO position, use the red meter lead test probe to take the following voltage readings. Use figure 1 and the one on the trainer and take voltage readings at the points indicated in figure 1. Record the readings as required in the following steps.

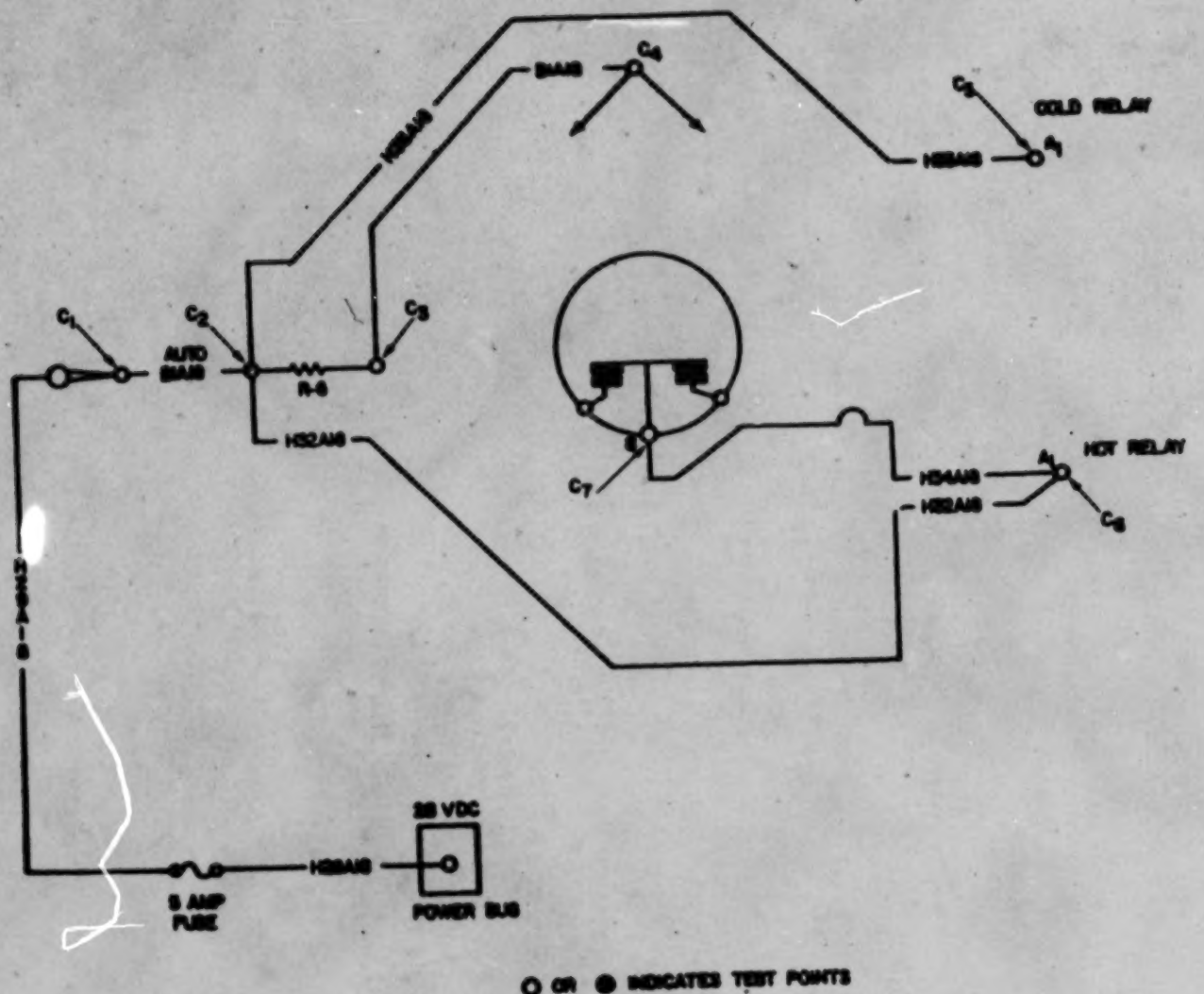

C4
C5
COLD RELAY
C1
C2
C3
AUTO
R-6
C7
HOT RELAY
C6
28 VDC
5 AMP
FUSE
POWER BUS
O OR ● INDICATES TEST POINTS

Figure 1.
8

(1) Test points are identified by C. Example C1, C2, C3, etc.

(2) Test point C1 indicates _____ volts.

(3) Test point C2 indicates _____ volts.

(4) Test point C3 indicates _____ volts.

(5) Test point C4 indicates _____ volts.

(6) Test point C5 indicates _____ volts.

(7) Test point C6 indicates _____ volts.

(8) Test point C7 indicates _____ volts.

Answers to the above test points can be found on page 13.

At test point C2 there was a three way junction. While you are at this junction it is always a good idea to pull a voltage check to A1 of the cold relay (C5). A voltage check to A1 of the hot relay (C6) and then on to pin 8 of the micropositioner armature contact (C7). These checkpoints indicate that at each, there is a 28V DC voltage potential waiting to go to work as soon as there is current across the micropositioner and either relay is energized.

Further note that only the portion of the bridge being checked is shown. If your answers do not agree with the ones above, repeat these checks. If your answers still do not match, notify the lab instructor.

Note: With voltage to C1 this indicates that the circuit is OK from the +28V DC power bus to this point. Checkpoint C3 indicates that there is a voltage drop across the voltage dropping resistor R-6. If you concur with the above then proceed on to the next step.

8. Now that you have determined that the circuit is OK to the top of the bridge, the next steps will be in checking out the "bridge" itself. Turn the meter to Ohms Range X 10 and zero the meter.

a. Turn the temperature control switch to "OFF." On the aircraft or any circuit that deals with temperature control circuits, you will have to isolate the circuit by turning circuit power off and checking the temperature sensors, rheostat and bridge wiring on ohms.

b. Before taking any resistance readings isolate the circuit even more by breaking the connections between the various sensors and resistors on the bridge. On the aircraft itself you would either have to unsolder some wires or disconnect the cannon plug from the temperature controller and take the readings (resistance) at the plug itself. You will find that this latter method is normally used to check the various bridge sensors and rheostat.

(1) On this particular circuit pull straight out on the two tie point jack, located at points A and B of the circuit. These are two meter rectangles that have 3 nuts and jacks on each plate.

(a) Upon completion of bridge resistance checks be sure to replace the plugs or you will be unable to get bridge operation.

(2) If you do not isolate the bridge in this manner you might read resistance in another part of the circuit. Refer to the illustration below. Study it carefully, note direction of meter current by direction of arrows, the open sensor (resistor) and the values of the other resistors.

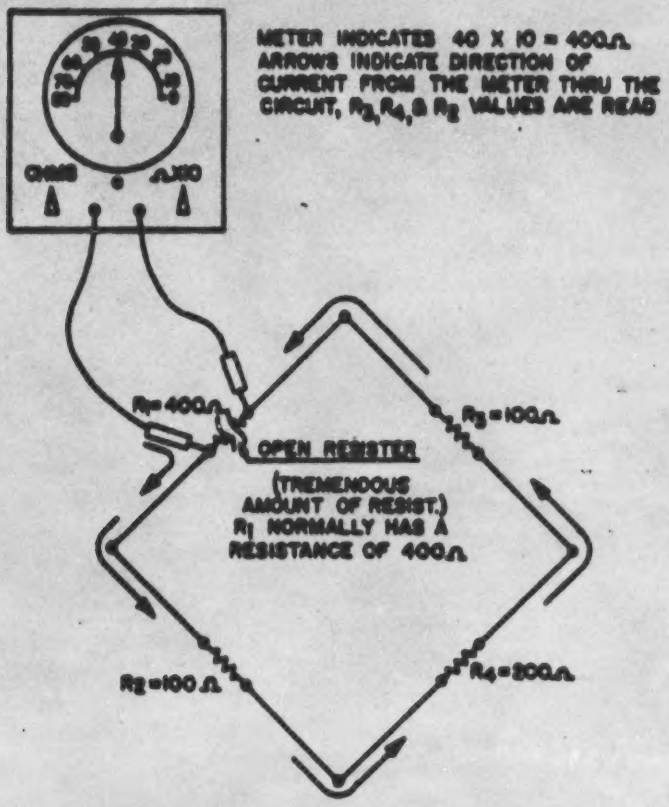

METER INDICATES 40 X 10 = 400Ω
ARROWS INDICATE DIRECTION OF CURRENT FROM THE METER THRU THE CIRCUIT, R3, R4, & R2 VALUES ARE READ
OHMS
ΩX10
R1=400Ω
OPEN RESISTER
(TREMENDOUS AMOUNT OF RESIST.)
R1 NORMALLY HAS A RESISTANCE OF 400Ω
R3=100Ω
R2=100Ω
R4=200Ω

Figure 2

(3) Note that the Ohmmeter is placed across the open resistor R-1. Note by the arrows that the meter is actually reading the TOTAL value of R-3, R-4, and R-2. Remember that the ohmmeter has its own power source and puts a small amount of current through the circuit being checked. This is necessary to get needle deflection on the meter.

(4) Referring again to the illustration, if the electrons had a choice to go through a tremendous amount of resistance (open ∞) or a small amount of resistance to get to a given point, which path would the electron flow? They will flow through a conductive path which will allow current to flow.

c. Using the illustration and the checkpoints listed on page 11, take the following resistance readings on the trainer and record your answers in the spaces provided. Indicate whether the meter indicated an open, short, continuity (0 ohms on straight run of wire) or resistance. (Resistors should indicate resistance.)

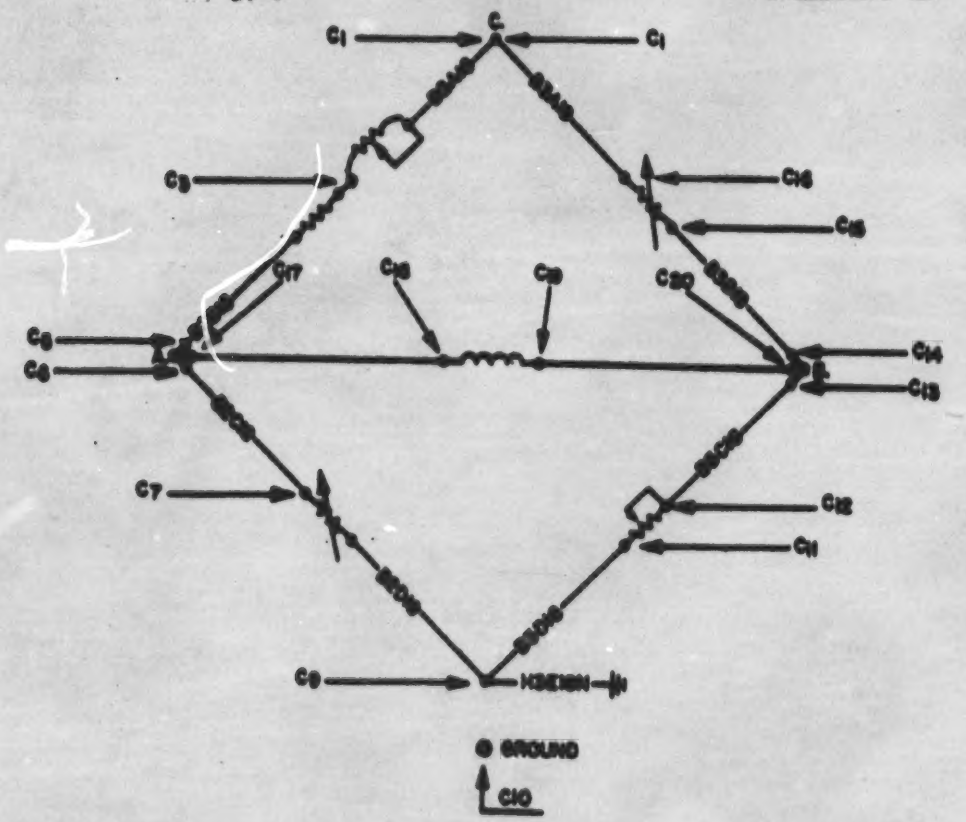


Figure 3.

CHECKPOINTS

C1 to C3 _____.

C3 to C5 _____.

C6 to C7 _____.

C7 to C9 _____.

C9 to C11 _____.

C11 to C12 _____.

C12 to C13 _____.

C14 to C15 _____.

C15 to C16 _____.

C16 to C1 _____.

The correct responses for the above can be found on page 13.

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d. The only thing left to check is the path across the bridge and the hot and cold relay circuits.

(1) Refer to figure 4 and take the following resistance readings at the checkpoints indicated. Indicate if it has continuity, resistance, is shorted, or open.

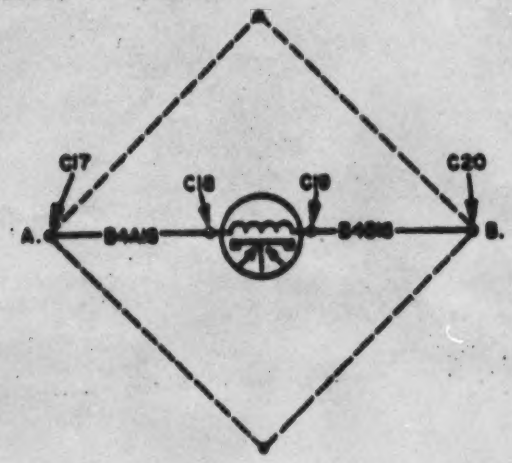


Figure 4.

C-17 to C-18 _____.

C-19 to C-20 _____.

C-18 to C-19 _____.

The correct responses for the above can be found on page 13.

e. Between points C-19 and C-20 the ohmmeter indicated infinity (∞). This shows that the path for current to flow from A to B is interrupted at this point. No current can flow across the micro-positioner coil, therefore, neither the hot nor cold relay can work. The temperature control valve will remain in its LAST position.

(1) By using this step-by-step procedure the problem has been located without too much difficulty. Remember to use these procedures when checking other malfunctions.

Note: The only units in the automatic circuit that were not checked were the hot and cold relay circuits and the ground for the relays. At this point if you suspected a problem in either relay you should be able to check it out by using the voltmeter from point-to-point. Remember, if you still have not located any troubles by the time that you reach checkpoint C20 then more than likely you do have a relay problem. When checking the bridge ground, motor ground, or relay grounds, turn the power on with both isolation tie point jacks installed and measure the DC voltage on ground. The DC meter should indicate "0" volts for good grounds and a voltage reading for an open ground.

Correct responses for figure 1:

C1 = 26 ± 4V DC

C2 = 26 ± 4V DC

C3 = 20 to 25 volts DC

C4 = 20 to 25 volts DC

C5 = 26 ± 4V DC

C6 = 26 ± 4V DC

C7 = 26 ± 4V DC

Correct responses for figure 3:

C1 to C3 - Resistance.

C3 to C5 - Resistance.

C6 to C7 - Continuity.

C7 to C9 - Resistance

C9 to C11 - Continuity.

C11 to C12 - Resistance.

C12 to C13 - Continuity.

C14 to C15 - Continuity.

C15 to C16 - Resistance.

C16 to C1 - Continuity.

If your answers do not agree with those above, recheck at the different checkpoints. If your answers still do not agree, notify the instructor. Up to this point all the circuits that have been checked indicate that they are GOOD.

Correct responses for figure 4:

C-17 to C- 18 Continuity.

C-19 to C-20 Open.

C-18 to C-19 Resistance.

f. You are now ready to do two more practice problems on your own. Use the space provided to record your findings. Note number #1 has been done for you. In the malfunction column provided, place the letter of the indicated malfunction from the list provided after the exercise.

Practice Problems

Trouble Switch #	Malfunction		Cause	
			Type of trouble open, short, etc.	Unit or wire Number
1	D	[redacted]	Open	B4 B18

Instructor's initial _____ Practice problem grade _____

A. No Manual Cold

B. No Manual Hot

C. No Operation (nothing works)

D. No Auto

E. Full Auto Cold

F. Full Auto Hot

G. No Auto Cold

H. No Auto Hot

If your lab instructor signs off your practice work, you will be assigned your progress check material.

REMEMBER! Check all circuits except the bridge circuit with a volt meter. The bridge circuit will be check with an ohm meter only. Also when you check the bridge circuit you isolate it by pulling the two metal jacks and replace them upon starting a new operational check.

PROGRESS CHECK INSTRUCTIONS

This progress check will require you to correctly solve a minimum of 4 out of the 5 problems given. This should be accomplished much in the same manner as the practice problems. The instructor will check and initial your work after the 5 problems are graded and passing. If you have missed more than one (1) problem you will follow your lab instructor's instructions.

You will not communicate (talk, etc.) with other students during the progress check without your lab instructor's permission.

You will not use fellow students work to solve the problems in this progress check.

You must satisfactorily complete this progress check before further progression to other lab troubleshooting progress checks.

Note: If any part of the answers (cause or malfunction) to the trouble switch # is wrong, the instructor will mark the whole trouble switch entry incorrect. This means YOU will have to find what part or parts to the cause or malfunction is incorrect for that trouble switch when marked incorrect.

Student complete the following (print).

STUDENT NAME _____
LAST FIRST

DATE PROGRESS CHECK STARTED _____

_____

PROGRESS CHECK

Trouble Switch #	Malfunction	Cause	
		Unit or Wire Number	Type of trouble open, short, etc.

Instructor's initial _____ Grade _____ On complete progress check

A. No Manual Cold
B. No Manual Hot
C. No Operation (nothing works)
D. No Auto
E. Full Auto Cold
F. Full Auto Hot
G. No Auto Cold
H. No Auto Hot

983

If you have satisfactorily completed the progress check, store your multimeter and trainer in the following way.

1. Pull out all the circuit breakers. (If any.)

2. Place the control switch in the OFF position.

3. Place all trouble switches toggles to the OFF position.

4. Insure all your training literature, pencils, etc. are taken with you when you leave the lab.

5. Insure your trainer and the area around it is clean before you leave the lab.

6. Properly store and sign in your multimeter before you leave the lab.

7. Check with the lab instructor before you leave the lab.

Note: Did you leave your multimeter set on OHMS?

If you have, go back and change it.

Technical Training

Aircraft Environmental Systems Mechanic

ALTERNATING CURRENT

13 January 1972

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes PT 3ABR42231-PT-113B, 3 December 1969.
OPR: TDAM
DISTRIBUTION: X
TDAM - 750; TTOC - 2

Designed For ATC Course Use

DO NOT USE ON THE JOB

FOREWORD

This Programmed Text was prepared for use in the 3ABR42231 instructional system. The material contained herein has been validated using thirty 42010 students enrolled in the 3ABR42231 course. Ninety percent of the students taking this text surpassed the criterion called for in the approved lesson objective. The average student required (28) minutes to complete the text.

OBJECTIVES

After having completed this Programmed Instructional Package, the student will be able to:

1. Plot an AC sine wave.
2. Label the components of an AC sine wave.
3. Determine the frequency.
4. Label the peak and effective voltages.

INSTRUCTIONS

This program presents information in small steps called "Frames." After reading the information in each Frame, you are asked to select an answer or make an entry that shows you understand the "information" in that Frame. You may write your answer in this booklet. You may check the accuracy of your answers by looking on the next page.

ALTERNATING CURRENT

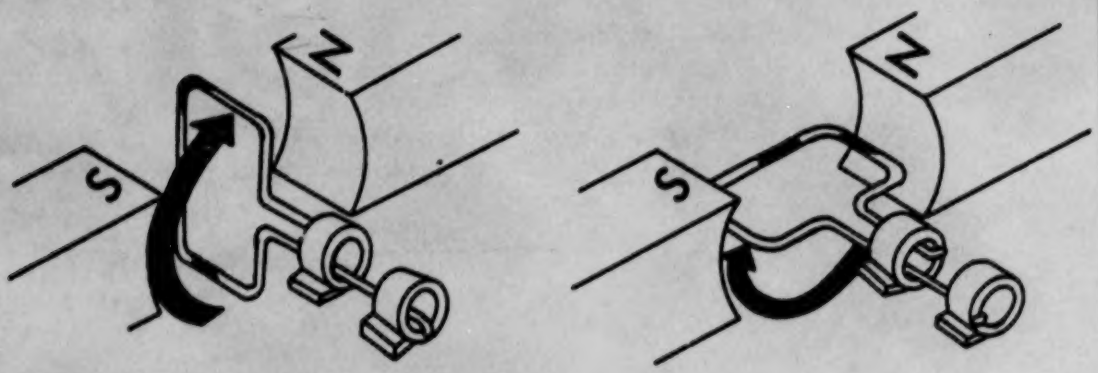
Alternating current and direct current are the two main forms of electrical power known to man today. You have already been introduced to direct current and to the method of producing it. In this unit of instruction we will deal almost exclusively with alternating current.

Alternating current is produced by the mechanical method. Both the alternating current generator and the direct current generator use the same principles of magnetism to produce a voltage. Both types of generators must have conductors, a magnetic field, and relative motion between the two. The difference in the type of output is controlled only by the internal parts of the generators.

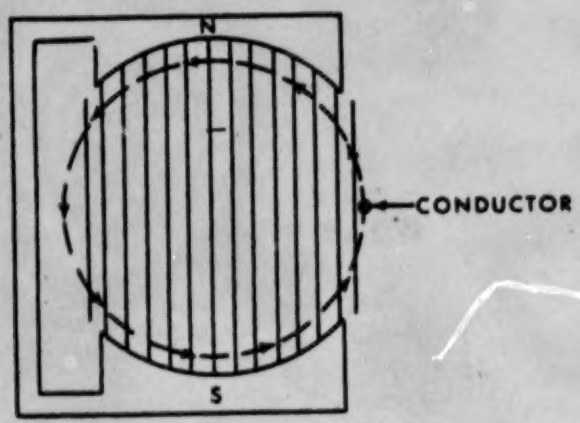
No response, go on to the next page

987
Frame 2

An AC generator has a conductor (actually many conductors) which rotates in a magnetic field. The diagram below shows a very basic AC generator, with a one wire conductor. Notice that the conductor is in the form of a loop, with a pivot point midway in the loop.



When one side of the loop is traveling up, the other side is moving down. The voltage buildup on one side of the loop always aids the voltage buildup on the other side. Since this is so, we will use only one of the conductors in the loop to explain how an AC voltage is produced. The diagram below represents this conductor in a magnetic field. (End view) If the conductor is rotated in a circle (represented by the dotted line) it will first cut across the magnetic lines of flux in one direction (right to left). Then it will cross the flux lines in the opposite direction (left to right). This causes current to flow first in one direction in the conductor, and then in the opposite direction.



No response, turn to the next page

1009½

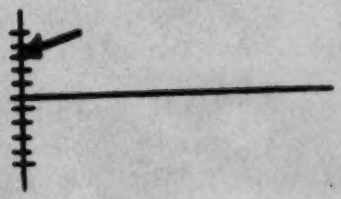
A sine wave is commonly used to represent this alternating current in a circuit. The next few pages in this program will teach you how this sine wave is developed and the terms used with it.

Let's start with the terms used when plotting a sine wave. The two solid lines in the diagram below are reference lines. In order to show how much voltage the generator is producing, the vertical line called an "Amplitude" line is used. This line is sometimes marked with numbers to represent specific voltage or current values.

Draw an arrow pointing to the amplitude line in the diagram above.

989
989

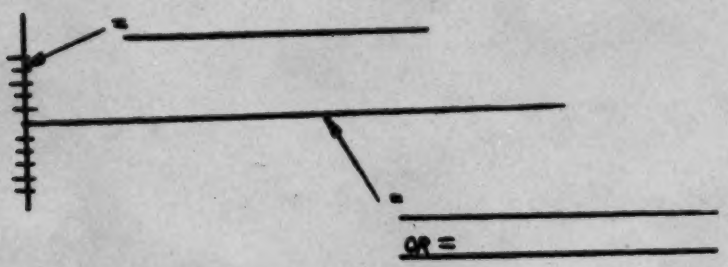
Answer to Frame 3:



Frame 4

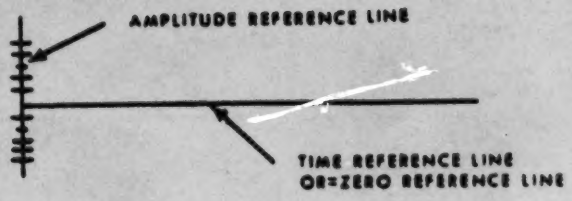
The horizontal reference line has two names. It can either be called a "0" (zero) reference line or a "time" reference line, for it represents both zero voltage and time.

Label the reference lines in the diagram below.



1011

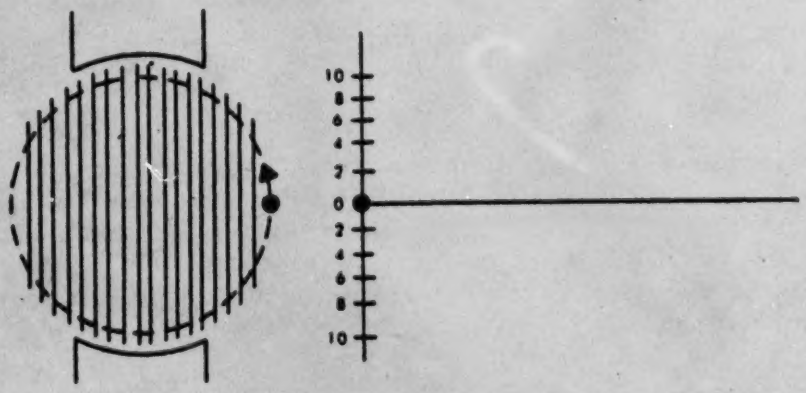
Answer to Frame 4:



Frame 5

Now let's combine the basic generator (one conductor) and the reference lines to show how a sine wave is produced.

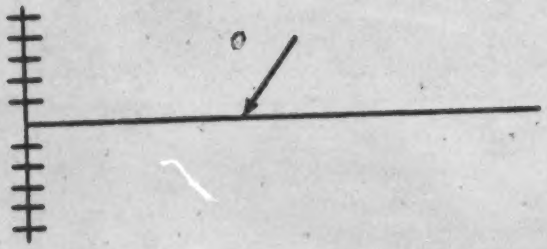
In the diagram below, the basic AC generator is producing no voltage. The conductor is moving parallel to the magnetic lines of flux at this instant, and therefore is not cutting across any lines. The "0" voltage produced at this time is represented by a dot on the zero reference line.



Draw an arrow to the "0" reference line in the diagram above.

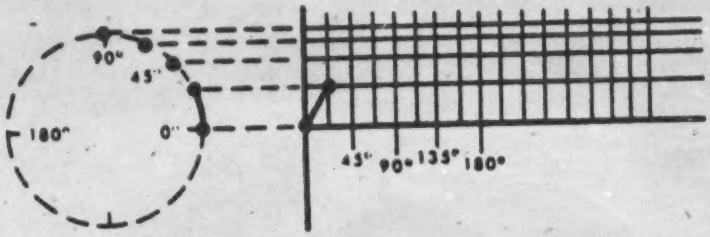
991

Answer to Frame 5:

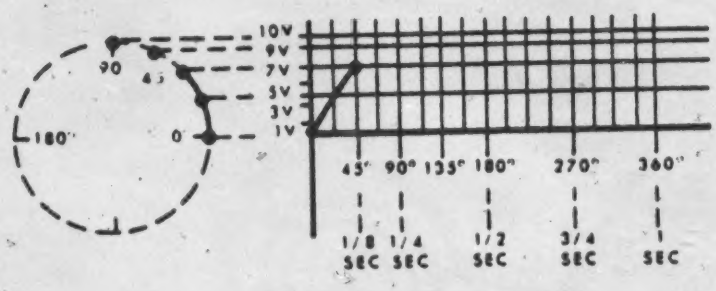


Frame 6

As the conductor rotates from the starting point through 22 1/2° of a complete circle, it begins to cut across lines of magnetic flux.



This produces a voltage in the conductor. The amount of voltage at this time is small, but it is building toward the maximum voltage the generator will produce. This small amount of voltage is shown on our reference lines by a rising line. (The start of our sine wave.) As the conductor continues to rotate, it cuts across more lines of flux and produces a higher voltage.



In the diagram above, the conductor has traveled 45° of a circle, and the voltage shown on the reference lines has risen higher.

What is the voltage at this time? _____

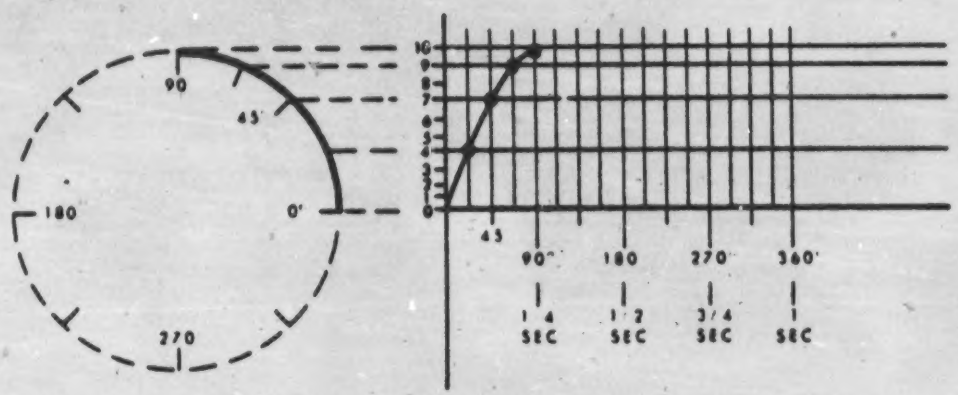
How long has it taken for this voltage buildup? _____

Answers to Frame 6: 7 volts

1/8 second

Frame 7

The conductor continues to rotate unitl it reaches 90°. (One quarter of a circle.) At this time the conductor is cutting a maximum number of flux lines and producing maximum voltage.



On the reference lines above, we have shown the voltage sine wave at its maximum height. Circle the letter before the correct answer.

1. What is the maximum voltage this generator is producing?
   a. 6 volts
   b. 8 volts
   c. 10 volts
   d. 12 volts

2. How long did it take to produce this peak (maximum) voltage?
   a. 1/8 second
   b. 1/4 second
   c. 1/2 second
   d. 3/8 second

3. How many degrees did the conductor travel to produce this maximum voltage?
   a. 45°
   b. 90°
   c. 180°
   d. 270°

4. At what point on the time reference line is maximum voltage shown?
   a. 45°
   b. 90°
   c. 180°
   d. 270°

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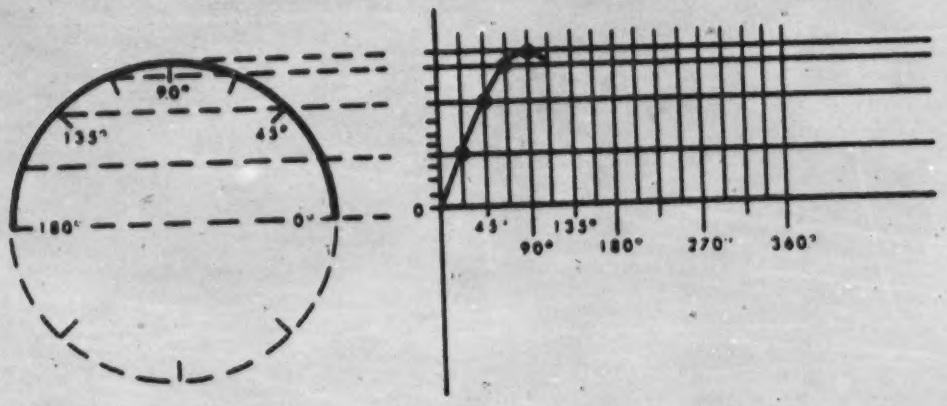
Answers to Frame 7:

1. c
2. b
3. b
4. b

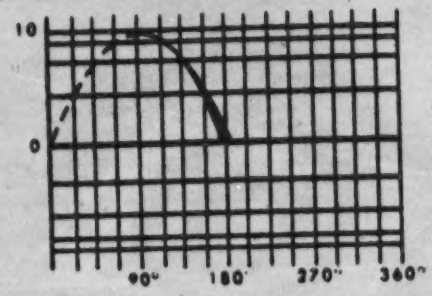
Frame 8

As the conductor continues to rotate to 180° of a circle it cuts fewer and fewer flux lines, until it is finally traveling parallel with the flux lines again, cutting "0" lines of force, and producing zero voltage.



Complete the portion of the sine wave on the reference lines above to show the drop of voltage to zero volts at 180°.

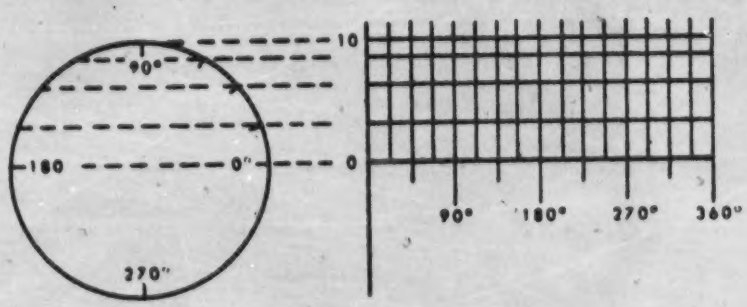
Answers to Frame 8:



The sine wave must be drawn so that it covers the corners where the graph lines cross.

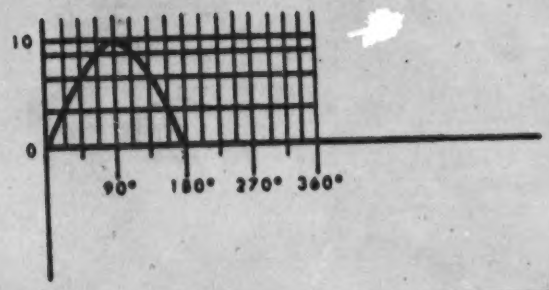
Frame 9

When the conductor has moved from 0° to 180° in a circle it has completed one alternation (one rise and fall of voltage from zero to maximum and back to zero volts). When the sine wave for one alternation is drawn above the zero reference line, it always indicates a positive (+) alternation. Plot a sine wave on the reference lines below, showing one complete positive alternation of voltage.



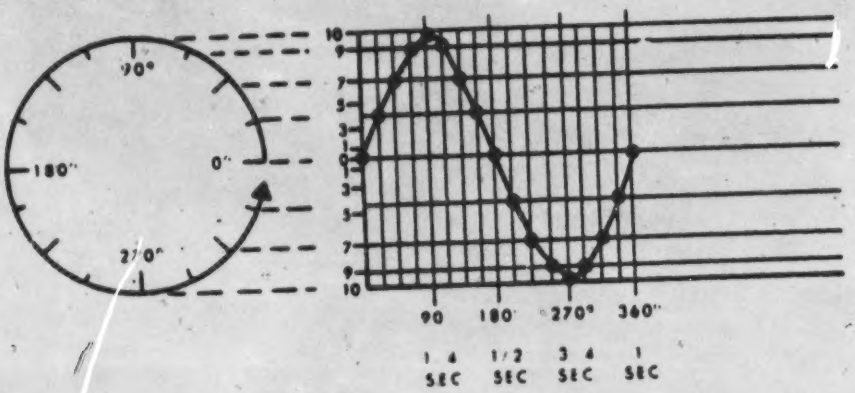
995

Answers to Frame 9:



Frame 10

When the rotating conductor completes the entire circle it first moves through the flux field in one direction, (0^{o} to 180^{o}) and then cuts across the flux field in the opposite direction. (180^{o} to 360^{o}) This is one complete cycle (a complete sequence of events), for the conductor is now back at "0" degrees of the circle, and starting on the second cycle. The first half of this cycle produced a positive alternation. The last half of the cycle produces a negative alternation. (A reverse in the direction of induced E.M.F.) This negative voltage buildup and collapse is always drawn below the zero reference line.



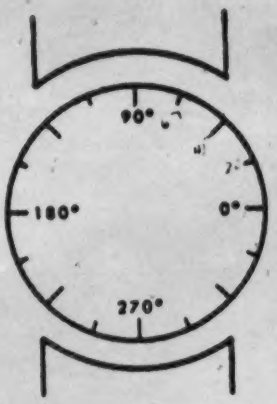
1. How long did it take for one complete cycle? _____
2. How long did it take for one complete alternation? _____
3. How many positive volts did the generator produce? _____
4. How many negative volts did the generator produce? _____
5. Would it be possible to produce more negative voltage than positive voltage with this generator? _____
6. At what point on the graph is maximum negative voltage shown _____^{o}
7. At what points on the graph are "0" voltages shown? _____^{o} _____^{o} and _____^{o}.

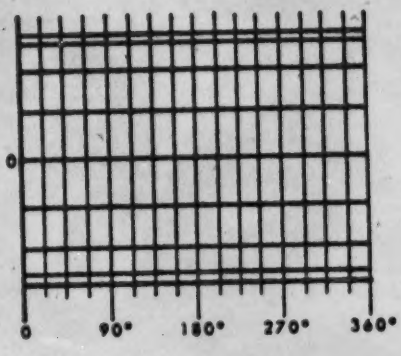
Answers to Frame 10: 1. 1 second 2. 1/2 second 3. 10V

4. 10V 5. no 6. 270° 7. 0, 180, 360

Frame 11

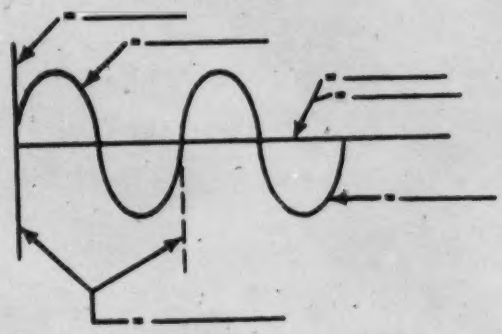
Plot a sine wave on the graph below, showing one complete cycle of AC voltage. Label each alternation as Positive or Negative.





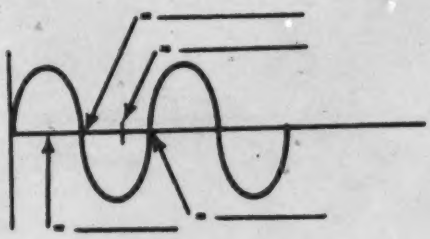
Label each of the following on the sine wave below.

Zero reference line
Time reference line
Amplitude reference line
One complete positive alternation
One complete negative alternation
One complete cycle



Label each of the following points on the sine wave below.

90°
180°
270°
360°



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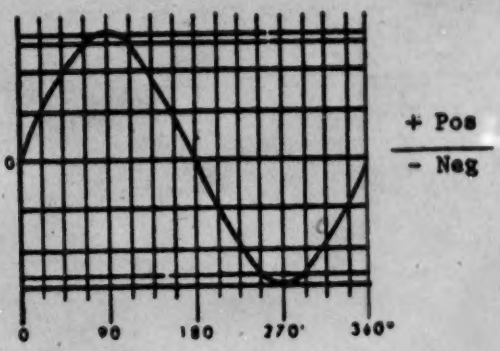
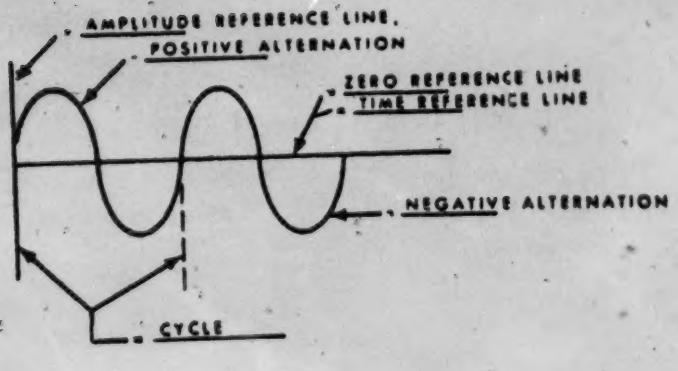
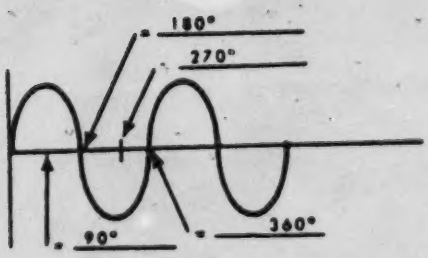
Answers to Frame 11:

Frame 12



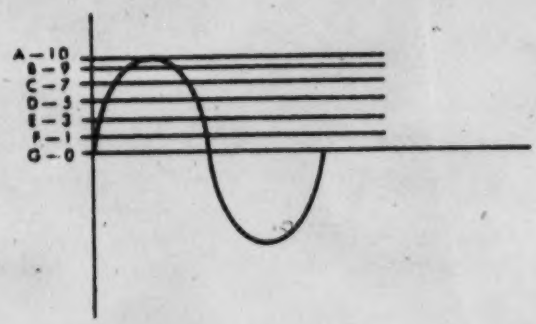




As you have seen, the generation of an AC voltage produces a sine wave that is constantly changing in amplitude and periodically changing in direction. The voltage is always rising or falling, and twice per cycle is at zero volts. Therefore, the amount of work a peak AC voltage can do is not equal to the amount of work an equivalent DC voltage can do. An AC voltage which reaches a maximum peak of 10 volts will do the same amount of work as 7.07 volts of DC.

Therefore, if we are referring to the effective voltage of an AC circuit it is only about 70% effective. It will only be .707 of the peak voltage.

Which of the lines across the positive alternation below represents effective voltage? (Circle the letter before the correct line)



999
Answer to Frame 13: c

Frame 14

Unless otherwise specified, all AC meters are calibrated to read the effective voltage of a circuit. The actual peak voltage will be higher than what your meter reads. There may be times when you will find it necessary to determine peak voltage. This can be done in one of two ways. Either divide the effective voltage by .707 or multiply by 1.414. Example:

```
        141.4
.707 / 100.000
       707
      2930
      2828
      1020
       707
      3130
```

```
  100
1.414
  400
  100
400
100
141.4
```

You will find these numbers in almost any book on electricity, if you need them, so we don't expect you to memorize them.

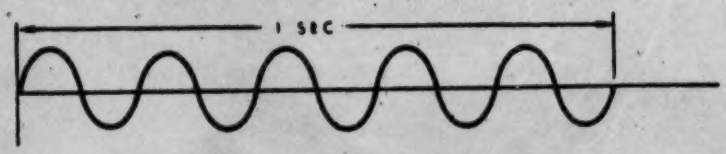
1. AC meters (unless otherwise specified) are always calibrated to read
   a. amperage voltage.
   b. instantaneous voltage.
   c. effective voltage.
   d. peak voltage.

Answers to Frame 14: c

1000

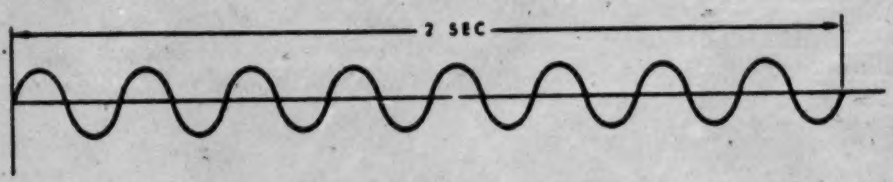
Frame 15

When our simple generator is turning at a speed of one revolution per second, it is producing one complete cycle per second (CPS). Another term for cycles per second (CPS) is Hertz. The number of cycles per second (Hertz) is called frequency. If the speed of the generator rotation were increased to 5 revolutions per second, the frequency of the output would then be 5 cps (Hertz). Frequency is always measured by the number of complete cycles in each second. The sine wave for 5 cps (Hertz) would look like this:



What is the frequency of the sine wave below?

a. 2 cps
b. 4 cps
c. 8 cps
d. 16 cps



Frequency is always measured in cycles per: (Circle the correct letter)

a. Microsecond.
b. Second.
c. Minute.
d. Hour.

1001
Answers to Frame 15: 4 cps b.

You have now completed this program. Please inform your instructor that you have completed the text.

S AFB. IL 72-21339

Technical Training

Aircraft Environmental Systems Mechanic

CAPACITANCE

31 July 1974

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR42231-PT-108B, 31 October 1972.
OPR: TAS
DISTRIBUTION: X
TAS - 150; TTOC - 2

Designed For ATC Course Use

DO NOT USE ON THE JOB

FOREWORD

This programmed text was prepared for use in the 3ABR42231 Instructional System. The material herein has been validated using thirty-seven 42010 students enrolled in the 3ABR42231 course. Ninety percent of the students taking this text surpassed the criterion called for in the approved lesson objective. The average student required 24 minutes to complete the text. The student will demonstrate his knowledge of the objectives by answering questions to an accuracy of 70%.

OBJECTIVES

When you have completed this programmed text, you will be able to:

1. Describe how capacitors are constructed.

2. Describe how capacitors store an electrical charge.

3. Explain the capacitor's ability to oppose any change in voltage.

4. Explain the capacitor's ability to cause current to lead voltage in a circuit.

INSTRUCTIONS

This program presents information in small steps called "frames." After reading each frame, you are asked to select an answer or make an entry that shows that you understand the information in that frame; do so by writing your answer in the response sheet. Do not mark in this text. You may check the accuracy of your response by checking correct responses at the top of every even numbered page.

Frame 1

You have learned about electron flow in a previous text. At this point, lets see how a capacitor would effect this flow. To start with lets answer the question, "what is a capacitor?" A simple definition of a capacitor is: "an electrical device capable of storing electrical energy." It would be quite possible at this time to confuse this definition with the definition of a battery, however, there is a essential difference between the two. A battery is a chemical generator which produces electrical energy as a product of chemical activity. A capacitor is a storage device (not a generator) which stores electrons.

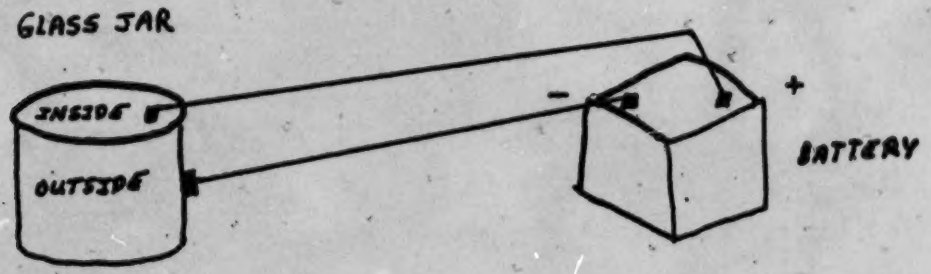


Figure 1 above, illustrates a glass jar, two conductors and a battery. The inside and outside of the glass jar is wrapped with copper foil. The positive terminal of the battery is connected to the inside piece of foil. While the negative terminal is connected to the outside piece of foil. There is no connection between the two conductors as the glass jar separates them. It insulates the inside and outside copper foil from one another. We now have the three essential parts of any capacitor; two conductors, and an insulator. Each of these three parts has a specific name. The conductor (inside foil) connected to the positive post of the battery is called the anode. The conductor (outside foil) connected to the negative post, is called the cathode. The insulator (glass jar) is called the dielectric.

Answer each of the following statements either true (T) or false (F).

_____1. The insulating material in a capacitor is called a dielectric.

_____2. A capacitor is a electrical device capable of storing electrical energy.

_____3. The glass jar used in figure 1 would be an example of a conductor.

_____4. The foil used in figure 1 would be an example of a insulator.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 2.

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Correct Responses to Frame 1: 1. T, 2. T, 3. F, 4. F.

Frame 2

Now that we have established that there is no electrical connection between the two conductors, (or plates as they are sometimes called) lets see how the electrons flow. The electrons in the negative plate want to pass through the dielectric to the positive plate. Thus, we can say that a potential exists between the two plates. The electrons tend to accumulate on the negative plate (see figure 2A below). If we disconnect the battery, electrons will be trapped on the surface of the negative plate (see figure 2B below). Now if we touch thy leads connected to the plates, the electrons will have a way to reach the positive plate (see figure 2C below). Since electron movement will be virtually instantaneous, a spark will be produced.

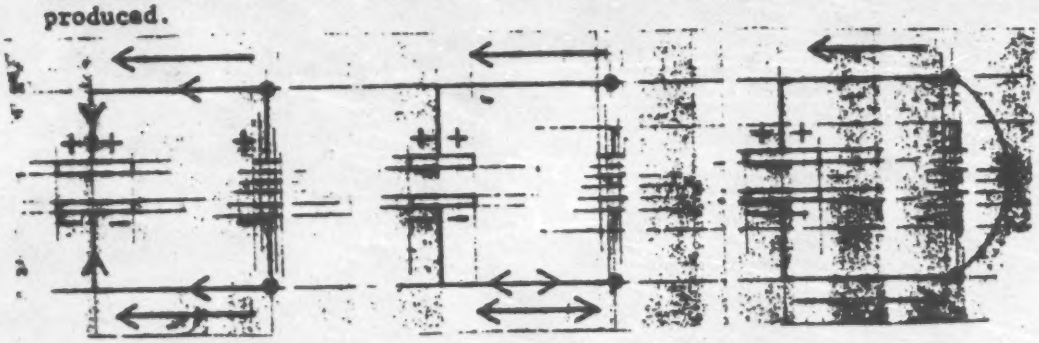


Figure 2A. Figure 2B. Figure 2C.

If the capacitor is removed from the circuit while still charged, we would have the equivalent of a small battery. It would not be a very useful battery however. For as soon as it was connected to a circuit, the electrons would leave the negative plate and attempt to reach the positive plate. Once this has occurred, the capacitor is discharged. Then the plates of the capacitor become two pieces of neutral metal. As the capacitor discharges through the circuit, it momentarily supplied a voltage. This voltage is almost as high as the original battery voltage due to the electron build up.

Indicate the letter of the correct response to each of the following statements.

1. When a charged capacitor is removed from a circuit, it will

   a. immediately charge.

   b. immediately discharge.

   c. retain its electrical charge.

Frame 2 (Cont'd)

2. A capacitor discharges with a voltage that is

   a. slightly higher than the applied voltage.

   b. slightly lower than the applied voltage.

   c. equal to the applied voltage.

SEE TOP OF PAGE 4 FOR CORRECT RESPONSES.

1007

Correct Responses to Frame 2: 1. c, 2. b.

Frame 3

The amount of charge that a capacitor can hold depends upon how it is constructed. This capacity for storing energy in an electric field is called capacitance. Three separate physical properties determine the amount of charge that any capacitor is capable of holding.

1. Plate Area - The larger the plate area, the more electrons it can hold; therefore, it has more capacitance.

2. Distance Between the Plates - When the distance between the plates is increased, the capacitance is decreased because the greater distance between the two plates reduces the attractive force between them.

3. Type of Dielectric - Electrons are easier to displace in some dielectric materials than they are in other dielectric materials. The type of dielectric, therefore, has a direct bearing on the capacitance of the capacitor.

Complete the following statement.

1. The three physical properties that determine the capacitance of a capacitor are:

   a. _____.

   b. _____.

   c. _____.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 6.

1029

Frame 4

Capacitors are effected more by temperature than by any other environmental conditions, except humidity. This is because capacitors are electrical devices and they store electrons. As the temperature increases, electron activity increases and as temperature decreases electron activity decreases. Therefore, when a circuit is designed to use a capacitor, the temperature factor must be taken into consideration.

NO RESPONSE REQUIRED

CHECK YOUR RESPONSE AT THE TOP OF PAGE 6.

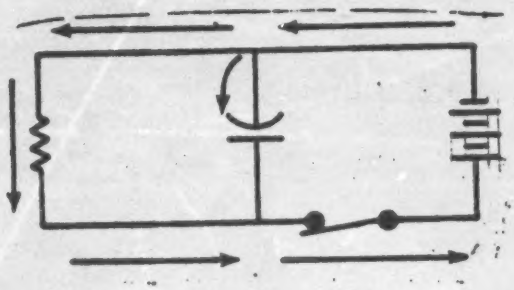
1009

Correct Responses to Frame 3: 1. a. plate area, b. distance between the plates, c. type of dielectric.

Correct Response to Frame 4: None Required.

Frame 5

A capacitor has the ability to oppose any change in voltage. To explain this more clearly, lets connect a capacitor in parallel with a resistor in a circuit. The symbol most commonly used to represent a capacitor is —| (— . (Positive —| , Negative (—)



When the switch is closed in the circuit above, voltage causes current to flow through the resistor. Full voltage is applied across both the resistor and the capacitor. The capacitor is being charged at the same time that current starts flowing through the resistor. When the capacitor has been fully charged (to a voltage almost as high as the battery voltage), there will no longer be a flow of electrons to the negative plate of the capacitor. Now all the electron flow will be through the resistor. (This applies to a DC circuit only.)

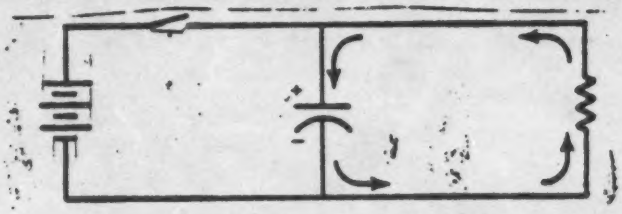
Indicate the letter of the correct response to each of the following statements.

1. A capacitor has the ability to oppose changes in
   a. current flow.
   b. voltage.
   c. frequency.
   d. resistance.

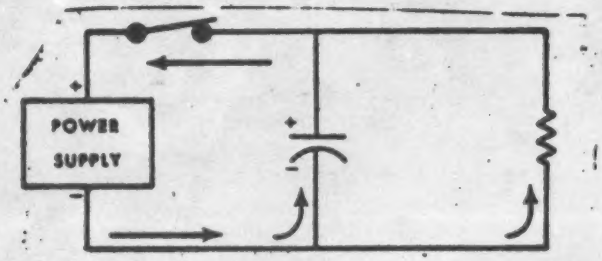
2. —| (— is the symbol for
   a. a capacitor.
   b. an inductor.
   c. reactance.
   d. impedance.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 8.

When the switch in the circuit below is opened, after the capacitor has been charged, the battery voltage is removed from the circuit. Voltage across the resistor is not removed though, because of the charge on the capacitor. The capacitor discharges across the resistor keeping the voltage applied for a very short time. The capacitor acting like a battery, opposes the decrease (change) of voltage across the resistor. This circuit was used for demonstration purposes only. A capacitor is not needed to keep the voltage constant across the resistor because the battery voltage does not fluctuate.



Suppose we need a constant voltage across a resistor, and the power supply fluctuates from 100 volts to 110 volts. Would a capacitor in this type circuit help us obtain a steady voltage? It certainly would! As the voltage from the source rises from 100 to 110 volts, the capacitor would continue to charge to the higher voltage. Now when the applied voltage drops back to 100 volts, the capacitor discharges electrons through the resistor. This action helps stabilize the voltage across the resistor.



Answer each of the following statements either true (T) or false (F).

_____1. The capacitor in the above circuit charges when the applied voltage increases.

_____2. The capacitor discharges through the resistor when the applied voltage decreases.

_____3. Fluctuations in applied voltage are not opposed by the capacitor.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 8.

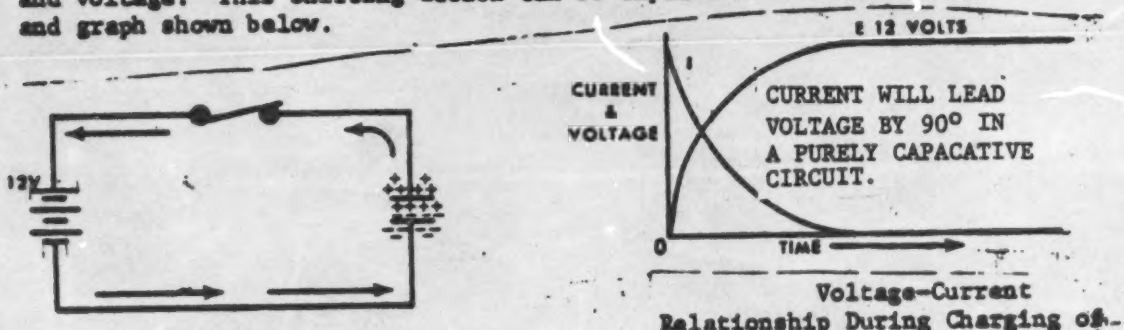
1011

Correct Responses to Frame 5: 1. b, 2. a.

Correct Responses to Frame 6: 1. T, 2. T, 3. F.

Frame 7

A capacitor in a circuit causes current to lead the voltage. That is, the capacitor causes a shift in phasing between the current and voltage. This shifting action can be explained with the circuit and graph shown below.



Voltage-Current Relationship During Charging of a Capacitor.

Before the switch in this circuit is closed, the capacitor has a neutral charge. In other words, its voltage is zero. As soon as the switch is closed, the 12 volts from the battery causes a maximum flow of current. As the current flow continues, the voltage at the capacitor increases. As the charge of the capacitor builds up, the difference in potential between the battery and capacitor plates becomes less. This causes a progressively decreasing current flow. When the capacitor is fully charged (maximum voltage), the current flow will stop completely (minimum current).

The graph shows the voltage-current relationship at the capacitor during the charging time. The vertical line at the left of the graph represents the voltage-current condition in the capacitor at the instant the switch is closed. The current (electron) flow is at maximum, and the voltage is at minimum. As the voltage increases, the current flow decreases. When the voltage has reached maximum (near 12 volts), the current flow has dropped to zero. If we compare this action with one-half cycle in an AC circuit, we can see that the capacitor causes the current to lead the voltage.

Answer each of the following statements either true (T) or false (F).

____1. At the time that the capacitor is fully charged (maximum voltage) the current flow is also maximum.

____2. The capacitor causes current to lead the voltage in the circuit.

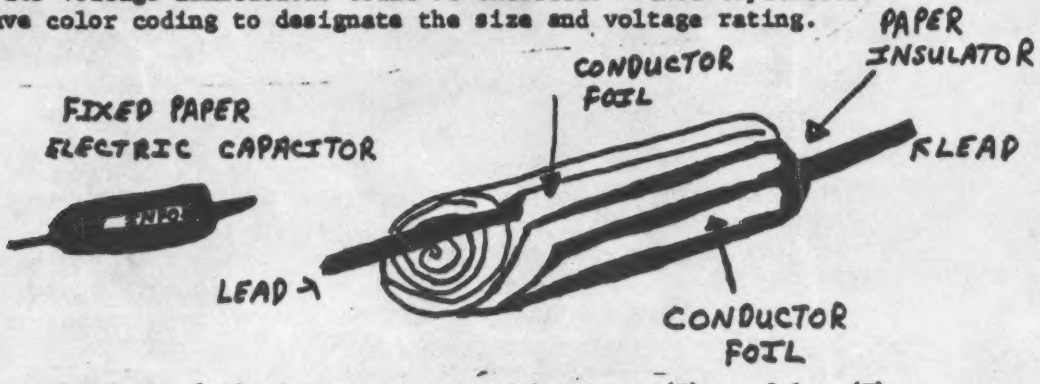
____3. At the instant that the capacitor is starting to charge, the current will be at maximum.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 10.

Frame 8

The unit of measurement for a capacitor is the farad. The letter "C" is the symbol of capacitance. If one coulomb (6.28×10^{18} electrons) will charge the capacitor to a one volt charge, the capacitor has one farad of capacitance. The farad itself is too large for practical use. Therefore, the unit of measurement actually used is microfarad. The microfarad is equal to one-millionth of a farad and is abbreviated mfd or µfd. The micromicrofarad is also used. It is equal to one-millionth of a microfarad and is abbreviated mmfd or pf.

Most capacitors also have a DC and an AC voltage rating stamped on them. This is to insure the capacitor will not be used in a circuit where its voltage limitations could be exceeded. Other capacitors may have color coding to designate the size and voltage rating.



Answer each of the following statements either true (T) or false (F).

_____1. The units of measurement for capacitance are the microfarad and the micromicrofarad.

_____2. An abbreviation for the microfarad is µfd.

_____3. The voltage ratings stamped on the capacitors should be observed when the capacitors are connected in circuits.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 10.

Correct Responses to Frame 7: 1. F, 2. T, 3. T.

Correct Responses to Frame 8: 1. T, 2. T, 3. T.

Frame 9

There are many different types of capacitors. Let's briefly describe a few different types so that you will be familiar with them.

One common type of capacitor is made by placing a long, narrow sheet of oiled paper between two similar sheets of tinfoil. Then another sheet of oiled paper is placed against the outside surface of each tinfoil sheet. These layers of tinfoil and paper are then rolled up and sealed in a cardboard tube. Two terminals are connected to the tinfoil and one extended to the outside of the tube.

The amount of voltage that can be applied to such a capacitor depends upon the insulating ability of the paper (dielectric). In other words, the dielectric of a capacitor determines the highest voltage that the capacitor can withstand without breaking down. When the plates are charged, electrons attempt to move from the negative plate to the positive plate. But, the dielectric prevents this from happening. However, depending upon the applied voltage and the type of dielectric's own electrons may break loose and move to the positive plate. This reduces the efficiency of the capacitor. Therefore, it is desirable to use dielectrics with high "electron holding" characteristics. This electron-holding ability of a dielectric is indicated by a numerical value which is called the "dielectric constant." The dielectric constant value compares the electron-holding quality of a dielectric, to a comparable insulating layer of dry air. For example, a nonconductor with a dielectric constant of 6, would be 6 times as good a dielectric as a layer of air of equal thickness.

The higher the dielectric constant, the better the quality of the dielectric. The dielectric constant rating is so important that capacitors are classified by the kind of dielectric used. The general types of capacitors, classified by dielectric, are; air, compressed-gas, vacuum, mica, ceramic, glass, oil, oil-paper, caster oil paper, chlorinated diphenyl-paper, and wax paper. The castor oil paper type of capacitor is one of the better paper capacitors.

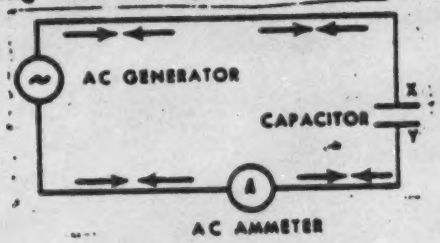
Answer each of the following statements either true (T) or false (F).

_____1. The dielectric of a capacitor determines the highest voltage the capacitor can withstand without breakdown.

_____2. Capacitors are distinguished by the type of dielectric they contain.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 12.

We have previously stated that DC voltage, when applied to a capacitor, causes current to flow only until the capacitor is charged. However, if an alternating (AC) source of power is substituted the capacitor will act differently. We stated (in a previous text) that one AC cycle would be half positive and the other half negative. As shown, in the next figure, current flow from the AC source will alternate. On the first cycle, Y would be positively charged, while X would receive a negative charge. On the next cycle, X would receive the positive charge and Y the negative charge. This alternation will continue with each cycle. No current will flow through the insulator (dielectric) between the capacitor plates. However, current will flow in the remainder of the circuit in between cycles. The amount of current flow, within the circuit, will increase if one or more of the following occurs: (1) The amount of applied voltage is increased, (2) the capacitor is replaced by a larger capacitor, or (3) the frequency of the applied voltage is increased. A capacitor, for an AC circuit, must be carefully chosen. The capacitor chosen must change fast enough to store the needed energy. Yet, it must discharge fast enough to avoid bucking the next cycle of current.



Answer each of the following statements either true (T) or false (F).

_____1. When a capacitor has AC applied to it, the charge on the capacitor constantly reverses.

_____2. When DC voltage is applied to a capacitor, the charge on the capacitor constantly reverses.

_____3. Current flow in the above circuit will change if the frequency of the applied voltage changes.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 12.

1015

Correct Responses to Frame 9: 1. T, 2. T.

Correct Responses to Frame 10: 1. T, 2. F, 3. T.

Frame 11

Capacitance may be compared to the elasticity, (springness) of a punching bag. Before the blow is delivered, the bag can be considered as being uncharged. Just as a capacitor is said to be uncharged before it has been connected across a power source.

Delivery of the boxer's punch causes the punching bag to move outward. The extent of movement depends upon the force exerted. Similarly, a capacitor accepts a charge. The strength of the charge is determined by the applied electrical energy.

The punching bag reaches the maximum distance it can move, in a given direction, because of the elasticity of its supports. This extreme distorted position represents stored energy, that flings the bag backward with almost equal force. This action may be compared to the action of the energy stored within a charged capacitor which is released when the capacitor is discharged.

Indicate the correct response to the following statements.

1. The strength of the capacitor's charge is determined by what?

   a. Magnetic field.

   b. Circuit resistance.

   c. Applied electrical energy.

   d. Current.

2. When is a capacitor said to be uncharged?

   a. After it has been connected to an emf.

   b. When it is gathering electrons.

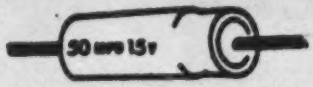
   c. Before an emf is connected to it.

   d. When current is flowing.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 14.

1037

Below are shown some different types of capacitors that are used in various circuits. Study the illustrations and become familiar with these different types of capacitors.

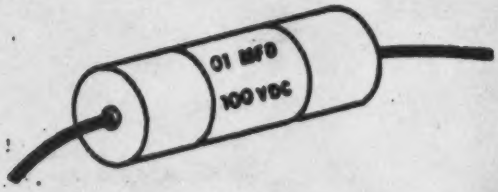


ELECTROLYTIC CAPACITOR

Most economical for AC motor starting circuits. Used with a centrifugal switch.

1. MFD 100 VOLT MINIATURE ELECTROLYTIC CAPACITOR

Most economical for AC motor starting circuits. Used with a centrifugal switch.



TUBULAR PAPER CAPACITOR

Has ability to withstand high voltages.

NO RESPONSE REQUIRED

CHECK YOUR RESPONSE AT THE TOP OF PAGE 14.

1017

Correct Responses to Frame 11: 1. c, 2. c.

Correct Response to Frame 12: None Required.

Frame 13

Answer each of the following statements either true (T) or false (F).

____1. The insulating material in a capacitor is called a dielectric.

____2. The size of the plates, the distance between the plates, and the type of dielectric determine the capacitance of a capacitor.

____3. Capacitance is measured in henries.

____4. When a charged capacitor is removed from a circuit, it immediately discharges.

____5. A capacitor has the ability to oppose any change in voltage.

____6. A capacitor causes current to lead the voltage.

____7. The voltage ratings on capacitors need not be observed when connecting the capacitors in AC circuits.

____8. Capacitors are distinguished by the type of dielectric they contain.

____9. When an AC voltage is applied to a capacitor, the charge on the capacitor constantly reverses.

____10. You should use caution when working with capacitors because of their ability to store an electrical charge.

Correct Responses to Frame 13: 1. T, 2. T, 3. F, 4. F, 5. T, 6. T, 7. F, 8. T, 9. T, 10. T.

Technical Training

Aircraft Environmental Systems Mechanic

INDUCTANCE

14 August 1972

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR42231-PT-113C, 27 May 1970.
OPR: TAM
DISTRIBUTION: X
TAM - 300; TTOC - 2

Designed For ATC Course Use

DO NOT USE ON THE JOB

1019

FOREWORD

This programmed text was prepared for use in the 3ABR42231 instructional system. The material contained herein has been validated using thirty-four 42010 students enrolled in the 3ABR42231 course. Ninety percent of the students taking this text surpassed the criterion called for in the approved lesson objective. The average student required (30) minutes to complete the text. The student will demonstrate his knowledge of the objectives by answering questions to an accuracy of 75%.

OBJECTIVES

After you have completed this programmed test you will be able to:

1. Use the left hand rule to determine the direction a magnetic field rotates around a conductor.

2. Describe how EMF is induced into a conductor by mutual induction.

3. Describe how EMF is induced into a conductor by self-induction.

4. Describe the effect counter EMF has on current flow in a coil.

5. Describe the characteristics of a coil that determines the amount of its inductance.

INSTRUCTIONS

This program presents information in small steps called "frames." After reading each step, you are asked to complete a statement or respond as directed. Use a piece of paper or a card as a mask to cover the printed material. Slide this mask down the page until you expose the top of a short row of slashes (//////////////). One small step is now exposed for your viewing. Read the material presented and make your response in the space(s) provided. Slide the mask down and compare your answer with the correct one. If you are wrong, read the frame again; if you are correct, go on to the next frame.

When current flows through a conductor, a magnetic field is created around the conductor. If the current increases, the magnetic field expands. To determine the direction that the magnetic field is rotating around the conductor, the left hand rule is used. The left hand rule is demonstrated below.

LEFT HAND RULE

Thumb Points In Direction of Current Flow and
Fingers Show Direction of the Rotating Magnetic Field.

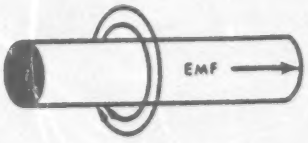
Whenever the direction of current is known, the direction of the rotating magnetic field can be found.

Whenever the direction of the magnetic field is known, the direction of the current flow can be found.

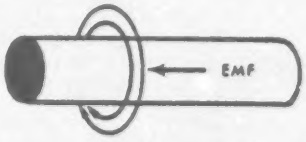
Circle the letter of the correct response to the following statements.

1. Which diagram below shows the correct direction of current flow?

a.

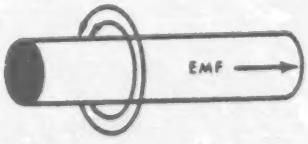


b.

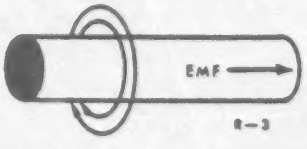


2. Which diagram below shows the correct direction of the rotating magnetic field?

a.



b.



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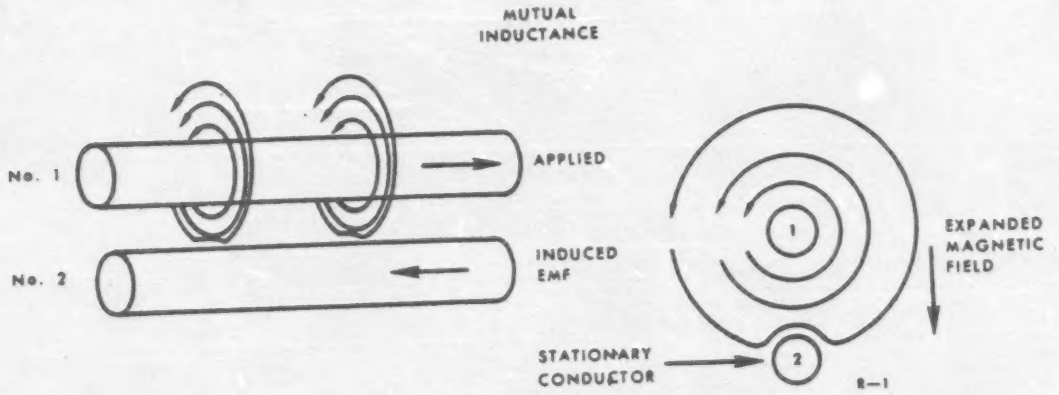
1021

Answers to Frame 1: 1. b. 2. a.

Frame 2

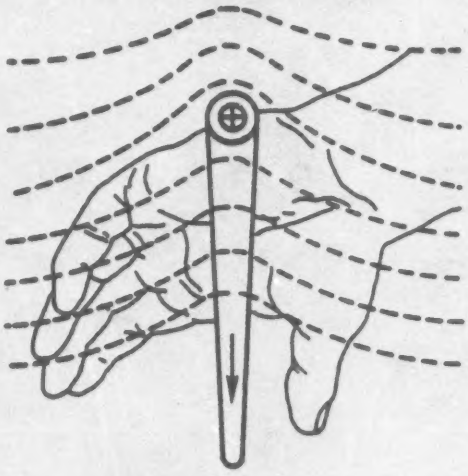
When two separate conductors are parallel to each other (adjacent) and one has current flowing through it, an electromotive force is induced in the adjacent conductor. Remember, to create an EMF, there must be a conductor, a magnetic field, and relative motion. The wires serve as conductors, as current flow increases through the first conductor an expanding magnetic field is created which cuts across the adjacent (No. 2) conductor, thereby producing an EMF. When current flow in one conductor produces an EMF in another conductor it is called mutual inductance. By using the left hand rule, we find that the EMF that is induced in the second (adjacent) conductor is in the opposite direction of the applied EMF.

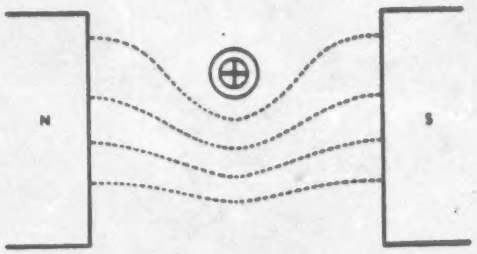


Let's look at these same two conductors from an end view. Curving the fingers of the left hand around No. 2 conductor the way that the field is bent, you can see that the thumb of your left hand indicates the induced EMF to be in the opposite direction as the applied EMF in the No. 1 conductor.

1043

Review the principle of operation of a basic generator as shown here. Follow the bent magnetic lines around the conductor with the fingers of your left hand and you see the current is flowing into the conductor away from you.





Current Flow in Wire Moving through a Magnetic Field

8—6

Notice that the conductor moves across the magnetic field in a generator, but isn't the result the same whether the conductor moves across the field or the field moves across a stationary conductor? Either way an EMF will be produced. Mark the following statements true (T) or false (F).

____1. When the conductor moves parallel with the magnetic field, no EMF will be produced.

____2. If a magnetic field moves across a conductor, an EMF will be produced.

____3. The EMF that a conductor induces into another conductor is called mutual inductance.

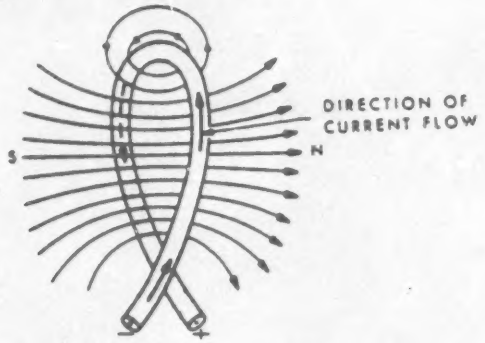
//////

1023

Answers to Frame 2: 1. T 2. T 3. T

Frame 3

A single conductor, when wound into loops, can induce an EMF within itself. When this occurs, it is called self-inductance. Also, when a conductor is wound into loops to form a coil, the strength of the overall magnetic field greatly increases. The amount of induced EMF therefore would be much greater.



Notice in the loop shown above, that the magnetic lines inside the loop aid each other to create a strong overall magnetic field. Consequently, when many loops form a coil, the self-inductance would be much greater. The letter symbol used to indicate inductance is "L." You may see the symbol in diagrams to represent a coil (inductance). The unit of measurement for inductance is the "henry."

Circle the letter of the correct answer to the following statements.

1. Self-inductance is a voltage produced
   a. by a chemical method.
   b. in a conductor by current flow in the same conductor.
   c. in a conductor by current flow in a different conductor.
   d. by mechanical means.

2. The letter symbol used for inductance is
   a. V.
   b. A.
   c. L.
   d. I.

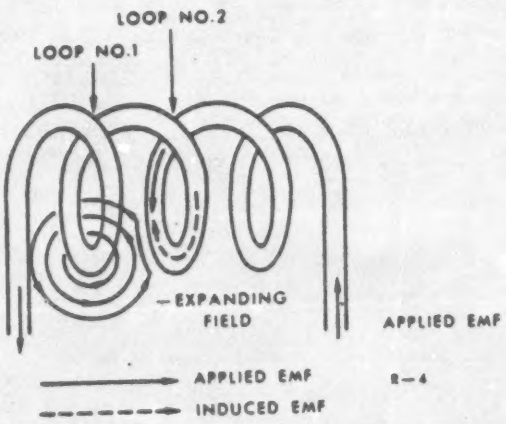
3. The amount of inductance in a single conductor can be greatly increased by
   a. forming the conductor into loops.
   b. increasing the length of the conductor.
   c. decreasing the length of the conductor.
   d. decreasing the applied EMF of the conductor.

4. The unit of measure for inductance is the
   a. henry.
   b. farad.
   c. ohm.
   d. amp.

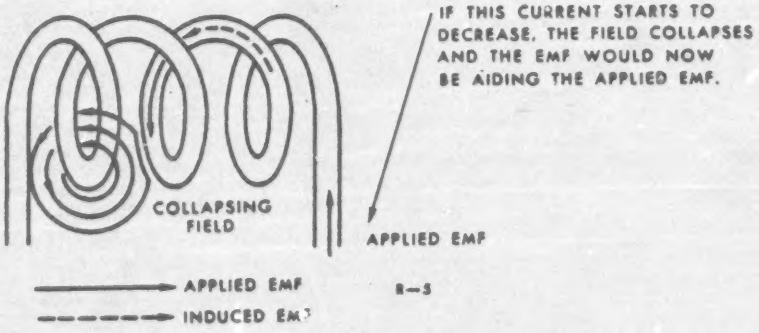
1045

Answers to Frame 3: 1. b 2. c 3. a 4. a

Frame 4



Looking at one expanding field as it cuts an adjacent conductor, (as shown above) we see that an induced EMF is produced which opposes the applied EMF. This action would be multiplied many times over if all the magnetic fields of all the loops were taken into consideration. Upon further examination, we can see that the induced EMF would also be created when the magnetic field collapses, but the induced EMF would now be in the opposite direction. A coil, therefore, has the ability to oppose <u>any</u> <u>change</u> in current flow. Notice that when current starts to increase in the coil, an expanding magnetic field produces an induced EMF which opposes the buildup of current. If the current in the coil tends to decrease, (as shown below) the expanded field collapses and creates a counter EMF that would try to keep current flowing in the coil.


IF THIS CURRENT STARTS TO DECREASE, THE FIELD COLLAPSES AND THE EMF WOULD NOW BE AIDING THE APPLIED EMF.
COLLAPSING FIELD
APPLIED EMF
APPLIED EMF
INDUCED EMF
R-5

Mark the following statements true (T) or false (F).

____1. A coil has the ability to oppose any change in current flow.
____2. The property of a coil to produce an induced EMF is called inductance.
____3. A coil will <u>only</u> oppose any change in current flow when its magnetic field is expanding.
____4. Energy is stored in the magnetic field of a coil.

//////

1025
Answers to Frame 4: 1. T 2. T 3. F 4. T

Frame 5

When an inductor is connected to a source of alternating voltage to form an inductive circuit, the current through the inductor lags the voltage across the inductor. This means that the current does not reach its maximum value until after the voltage has reached its maximum value. The current lags the voltage in a purely inductive circuit by 90°.

Mark the following statements true (T) or false (F).

__ 1. The current in an inductor does not reach its maximum value until after the applied voltage has reached maximum.

___ 2. In a pure inductive circuit, the current lags the voltage by 90°.

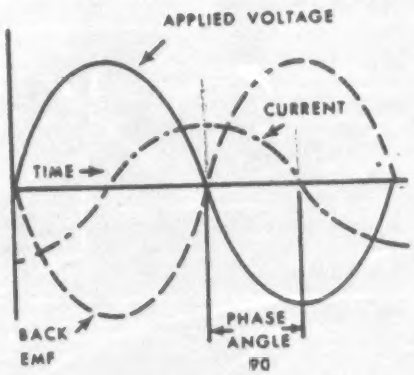
//////

1047

Answers to Frame 5: 1. T 2. T

Frame 6

Suppose that current is starting to flow through a coil. The current causes an expanding magnetic field which causes a back EMF to be induced in the coil. The polarity of the back EMF is opposite to the polarity of the applied voltage across the coil, and it, therefore, tends to oppose the increase in current. The result is that the rise in current flow is caused to lag behind the rise in voltage.



CURRENT LAGS VOLTAGE BY 90

8—7

The illustration above shows that the induced (back) EMF is always in opposition to the applied voltage, thereby causing current to be minimum when the applied voltage is at its maximum value. Notice that current in the coil does not reach its maximum value until the applied voltage has dropped to zero. You can clearly see that there is 90° difference between the applied EMF and current flow in the coil.

//////

No Response Required.

1027

Frame 7

As current increases through the coil, energy is stored in the expanded magnetic field. When the applied voltage starts to decrease from maximum positive, the stored energy is returned to the circuit in the form of current flow. This current flow is actually greater than the current flow caused by the applied EMF alone.

When the negative portion of the applied voltage occurs, a similar action takes place and maximum current will flow in the reverse direction at the instant that the voltage has decreased to zero from its maximum negative direction.

Mark the following statements true (T) or false (F).

____1. The applied voltage on a coil causes an induced EMF that is 180° out of phase with the applied voltage.

____2. The energy stored in the magnetic field can cause a greater current to flow than the applied voltage does alone.

____3. Current <u>leads</u> voltage by 90° in an inductor.

//////

Answers to Frame 7: 1. T 2. T 3. F

Frame 8

Some of the main physical characteristics of a coil that determine the amount of its inductance are:

1 - number of turns (loops)

2 - spacing of the turns

3 - type of core

Let's first discuss the effect that the number of turns has on inductance.

Assume that a coil has a given number of turns and is carrying a definite amount of alternating current. If some turns are added to the original turns, the current flow through the total number of turns will create a stronger magnetic field. This stronger magnetic field will induce a greater back EMF in the original turns. In addition the stronger field also cuts the added turns. Both of these factors cause an increase in inductance. Look at the illustration below for a comparison of two coils with different numbers of turns.

Circle the letter of the correct response to the following statements.

1. If the amount of current flow is the same in the coils above, coil "B" has

   a. less inductance than coil "A."
   b. more inductance than coil "A."
   c. a weaker magnetic field than coil "A."
   d. the same strength magnetic field as coil "A."

2. The inductance of a coil can be increased by

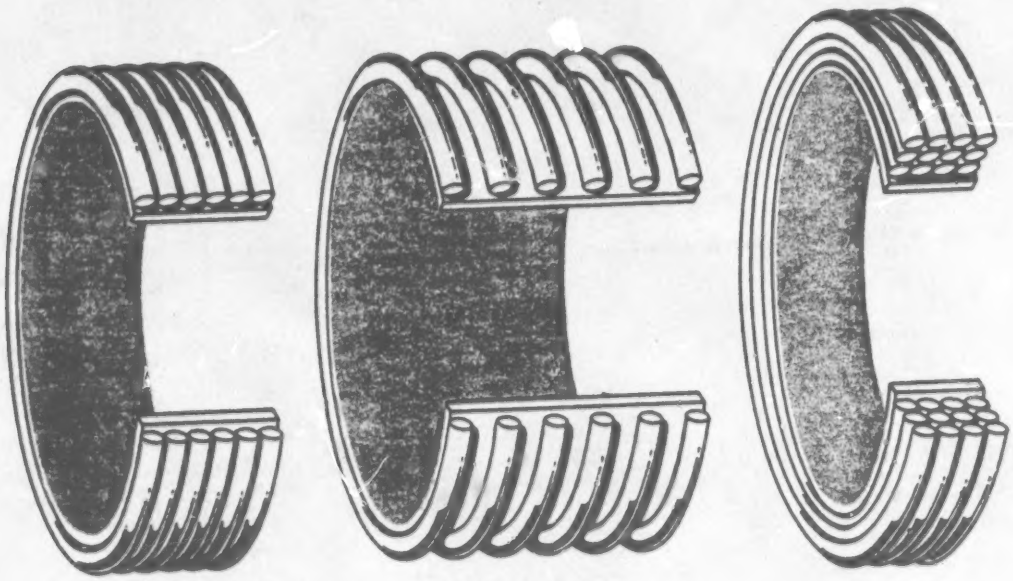
   a. decreasing the current flow through it.
   b. increasing the current flow through it.
   c. adding more turns.
   d. decreasing the number of turns.

//////

1029
Answers to Frame 8: 1. b 2. c

Frame 9

There are a number of methods of winding coils. Some coils are wound so that adjacent turns touch each other (Close Wound). Others are wound so that there is a certain amount of space between adjacent windings (Space Wound). The space wound coil has less inductance than the close wound coil because the magnetic field has farther to travel to cut an adjacent conductor. The third common type is the layer wound coil which has more inductance than either of the previously mentioned types since its individual magnetic fields are more concentrated with respect to the adjacent turns.



TYPES OF COIL WINDINGS

//////

No Response Required.

1051

The third main factor that affects inductance is the type of core being used. The inductance of a coil is directly proportional to the permeability of the core. (Remember that permeability is the ease with which a material passes magnetic lines of force.) Typical nonmagnetic core coils are those that are wound on hollow porcelain cylinders and hollow cardboard cylinders. The core material in these coils is air. Magnetic-core coils are wound on cores of soft iron. Since the soft iron core is very permeable, it provides an easy path for the magnetic lines and allows a much stronger magnetic field to build up. A greater back EMF is induced in the iron core coil as compared to the air core coils.

Place the letter of the statement in Column A in the appropriate spaces of Column B.

Column A	Column B
A - Increases inductance	____1. Removing the iron core from a coil.
	____2. Using close-winding method rather than space-winding.
B - Decreases inductance	____3. Decreasing the number of turns of the coil.
	____4. Winding the turns farther apart.
	____5. Winding the turns in layers.
	____6. Using a soft iron core instead of an air core.

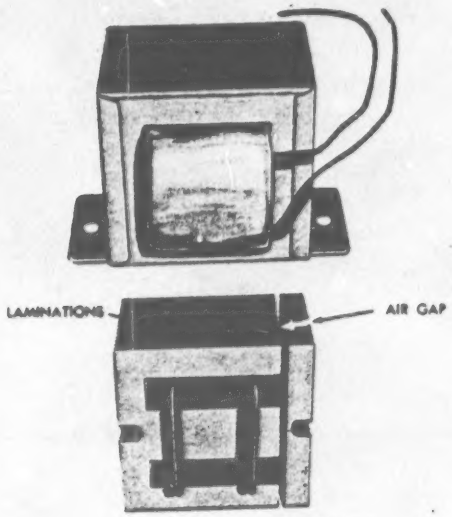
//////

1031

Answers to Frame 10: 1. B 2. A 3. B 4. B 5. A 6. A

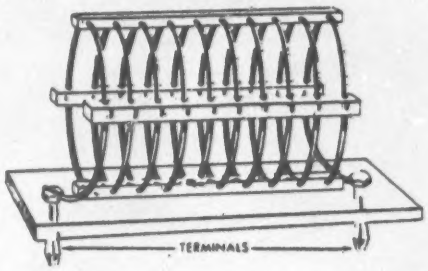
Frame 11

Familiarize yourself with the illustrations of various coils below. Sometimes the word "choke" is used interchangeably with the word "coil."

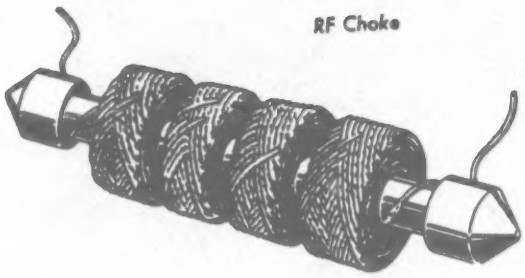


Laminated Iron-core Coil

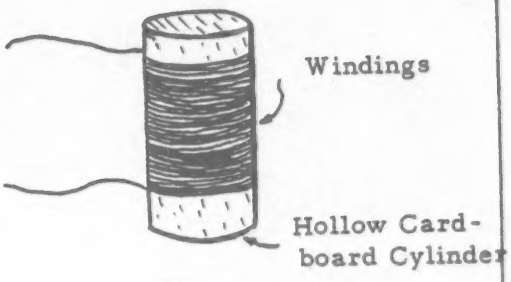
Fixed Tuning Coil



AIR CORE COIL



RADIO FREQUENCY COIL



COMMON TYPE AIR CORE COIL

//////

No Response Required.

12

Mark the following statements true (T) or false (F).

___1. The left hand rule can be used to determine the direction of a rotating magnetic field around a conductor if the direction of current flow is known.

___2. An inductor causes current to lag voltage by inducing a back EMF.

___3. The EMF that a coil induces within itself is called mutual inductance.

___4. A coil has the ability to oppose any change in current flow because it produces an induced EMF.

___5. The ability of a coil to produce an induced EMF is called capacitance.

___6. Inductance is measured in units called henries.

___7. In a pure inductive circuit, the current lags voltage by 90°.

___8. The current in a coil does not reach its maximum value until <u>after</u> the applied EMF has reached maximum.

___9. The amount of inductance of a coil is determined by its physical characteristics such as number of turns, spacing of turn, and type of core material.

___10. Energy is stored in the expanded magnetic field of a coil.

___11. Coils having soft iron cores provide less inductance than a comparable coil that has a core of air.

___12. When energy that is stored in the magnetic field of a coil is returned to the circuit, a greater current is caused to flow than can be caused by the applied EMF alone.

//////

1033

Answers to Frame 12:

1.	T	2.	T	3.	F	4.	T	5.	F
6.	T	7.	T	8.	T	9.	T	10.	T
11.	F	12.	T						

1055

S AFB, IL 73-24158

Technical Training

Aircraft Environmental Systems Mechanic

AC MOTORS

3 July 1974

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes Programmed Text 3ABR42231-114, 29 September 1972.
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1035

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FOREWORD

This programmed text was prepared for use in the 3ABR42231 instructional system. The material contained herein has been validated using thirty-seven 42010 students enrolled in the 3ABR42231 course. Ninety percent of the students taking this text surpassed the criterion called for in the approved lesson objective. The average student required forty minutes to complete the text.

OBJECTIVE

After having completed this programmed text, the student will answer discrimination type questions on principles of operation of AC motors, major parts of an AC induction motor, and types of AC motors, with a minimum of 70% accuracy.

INSTRUCTIONS

NOTE: BEFORE PROCEEDING, REMOVE THE RESPONSE SHEET AT THE BACK OF THIS TEXT. ENTER YOUR ANSWERS ON THE REMOVED RESPONSE SHEET

This programmed text presents information in small steps called frames. Each frame is followed by some form of questioning. Immediately after reading each frame, you will make the required response in the response sheet. DO NOT MARK IN THE TEXT. Check your answer each time with the correct answer shown at the top of each even numbered page. If you have made the correct response go on to the next frame. If you have made an incorrect response, reread the frame before going on to the next frame. Be sure you understand the material presented in each frame before continuing. Do not hurry!

Frame 1

Since alternating current (AC) is the most widely used form of power, most modern motors operate from an AC source. There are two general types of AC motors used on aircraft. They are called synchronous and induction motors. Either type of motor may use single or multiphase power. The induction motor is more often used because of its simple construction and reliability.

In the response sheet mark the following statements (T) true or (F) false.

1. Two types of AC motors are induction and synchronous.

2. Induction type AC motors use single phase power only.

3. The induction motor is often used.

CHECK YOUR RESPONSE AT THE TOP OF PAGE 2

Frame 2

For the purpose of this text we will be primarily concerned with the two parts of an AC motor. The parts are the ROTOR and the STATOR. When assembled together inside a case they form an AC motor. It is the action of these two parts that cause the motor to operate.

NO RESPONSE REQUIRED

Frame 3

The stator is mounted in a fixed position inside the motor case. Although the stator doesn't move its purpose in an AC motor is to create a rotating magnetic field for motor operation. The stator consists of a laminated iron field pole assembly with insulated copper wire wound on the field poles. The Field pole assembly is installed in a housing. When power is applied to the STATOR windings the stator is said to be EXCITED.

In the response sheet mark the following statements (T) true or (F) false.

1. The stator of an AC motor does not move.

2. The stator creates a rotating magnetic field.

3. The stator consists of two copper poles and an iron housing.

CHECK YOUR RESPONSE AT THE TOP OF PAGE 2.

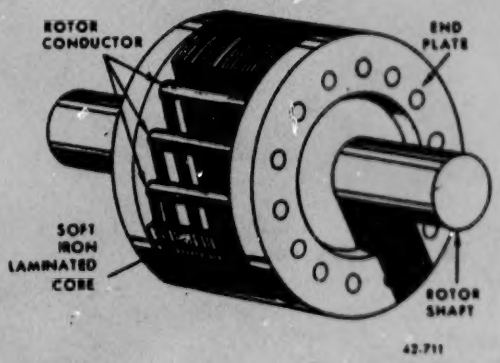
CORRECT RESPONSES TO FRAME 1: 1. T, 2. F, 3. T.

CORRECT RESPONSES TO FRAME 2: None Required.

CORRECT RESPONSES TO FRAME 3: 1. T, 2. T, 3. F.

Frame 4

The ROTOR is the portion of the AC motor that turns. There are two types of rotors used in AC motors. They are the SQUIRREL CAGE and the WOUND. The squirrel cage is more often used in environmental systems work so we will confine our discussion to it. (See illustration). The squirrel cage rotor has two end plates made of soft iron, a good conducting material. These plates are connected together by iron rods (rotor conductors). The iron rods are imbedded in the end plates to provide better conduction of the magnetic lines of force. The rotor of an induction motor does not have any electrical connections. The rotor has current flowing through it. Current flowing in the rotor is INDUCED current from the stator. The induced current in the rotor will create a magnetic field in the rotor. The magnetic field in the rotor follows the rotating magnetic field of the stator.



Fill in the missing information, in the response sheet, for the following statements.

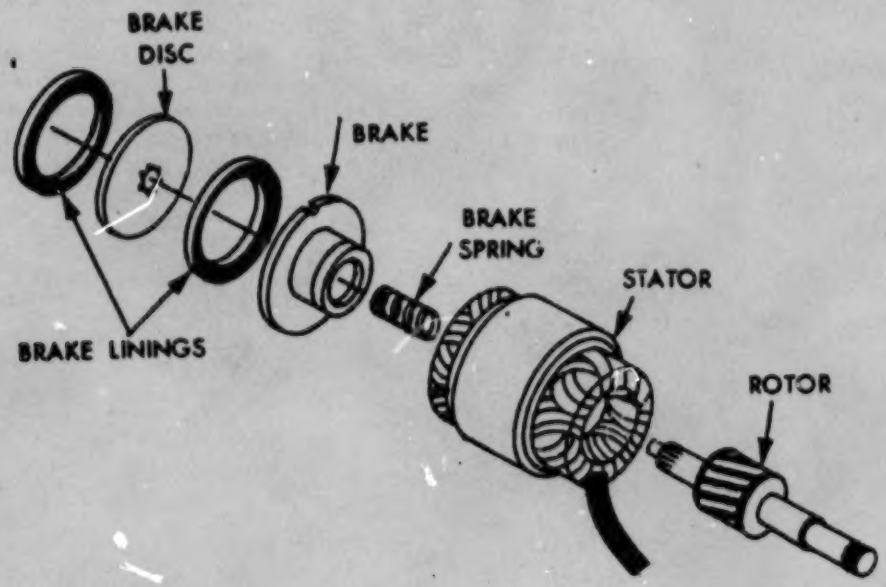
1. The current flowing in the rotor is _____ current.

2. The rotating magnetic field of the _____ will cause the _____ to turn.

3. The rotor of an induction motor doesn't have _____ _____.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 4.

Since induction motors used in environmental systems work are primarily reversible type, a brake assembly is sometimes used. The brake is designed to prevent overtravel (coasting) of a motor after current has been turned off. The brake is spring loaded ON and electrically disengaged. The illustration shows one type of brake with the rotor and stator. The unit uses the magnetic field of the rotor to disengage the brake. When power is applied the brake disengages and the motor turns. When power is stopped the spring pushes the brake against the brake disc stopping the motor. On AC motors that do not use a brake, a limit switch that you studied in the text on DC motors is used.



In the response sheet mark the following statements (T) true or (F) false.

1. Most AC motors used in environmental systems work are reversible.
2. The brake is spring loaded ON and electrically disengaged.
3. Some AC motors use limit switches to prevent overtravel.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 4.

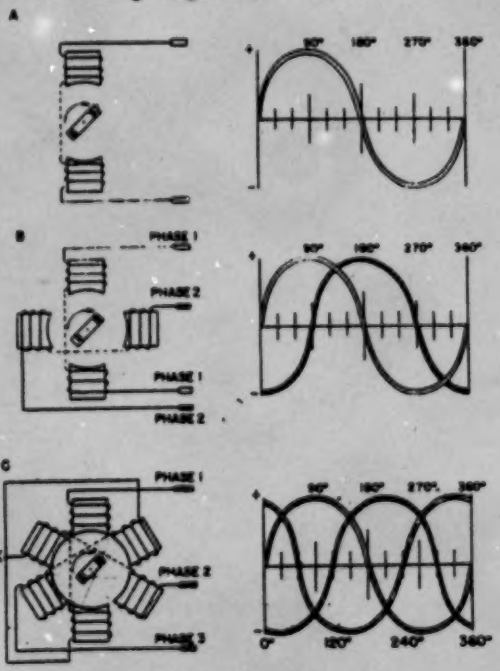
1039

CORRECT RESPONSES TO FRAME 4: 1. induced, 2. stator, rotor, 3. electrical connections.

CORRECT RESPONSES TO FRAME 5: 1. T, 2. T, 3. T.

Frame 6

To understand how an AC motor operates, an understanding of AC phase relationships is necessary. The illustration shows the sine waves for single, two- and three-phase power. Figure A shows the sine wave for single-phase power, you studied in an earlier text. Figure B shows the sine wave for two-phase AC power. Phase 1 is indicated by the white sine wave and phase 2 by the black sine wave. Phases 1 and 2 are two independent power supplies coming from the same source. These power supplies are 90 degrees out-of-phase. This means that by moving 90 degrees from the zero reference point phase 1 is at maximum value. At the same time phase 2 is at zero. Move 90 degrees further to the 180 degree point, phase 2 is at maximum. Phase 1 has dropped to zero. The phase changes occur in much the same manner in figure C except the three-phase power is 120 degrees out-of-phase. A study of the sine waves will show that each of the phases shown in figures B and C are at a different value at the same point in time. Because of this, each phase can be connected to different sets of poles in an AC motor to create a rotating magnetic field.



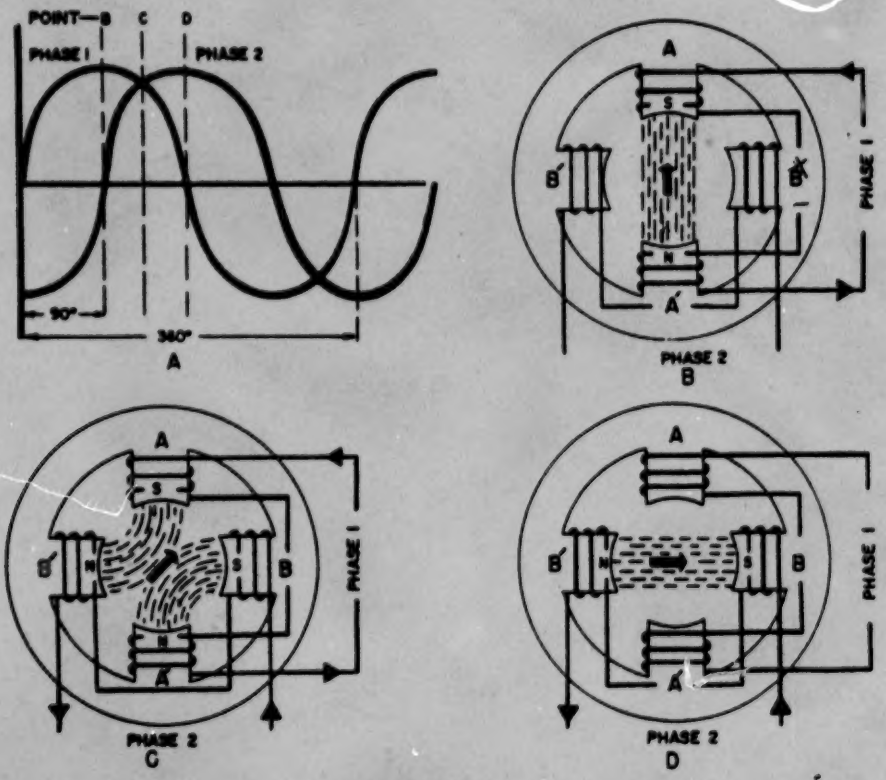
In the response sheet mark the following statements (T) true or (F) false.

1. Three-phase power has three independent power supplies from a common source.

2. Two-phase power is 90 degrees out-of-phase.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 6.

The stator is excited by applying AC power to the windings around the stator poles. This will establish a rotating magnetic field for motor operation. The magnetic field moves from pole piece to pole piece as the applied AC power changes value. The illustration shows the rotating magnetic field of a 2-phase AC motor. Phase 1 is connected to the poles marked A and A'. Phase 2 is connected to the poles marked B and B'. The position of the magnetic field in relation to applied current values can be seen by comparing the sine waves in figure A with figures B, C and D. At point B of figure A phase 1 is at maximum value. At the same time phase 2 is at zero. The magnetic field will be as shown in figure B. Current flow will be in the direction as shown by the black arrow. At point C both phase 1 and 2 are NEAR maximum and the magnetic field moves clockwise. Indicated by the black arrow in the center of figure C. With current at the values of point D the magnetic field is as you see it in figure D.



Fill in the missing information in the response sheet for the following statements.

1. At point D of figure A phase 1 is at _____ and phase 2 is _____.
2. The stator is excited by applying AC power to the _____ around the _____ _____.
3. Phase 2 is connected to the poles marked ___ and ____.
4. The magnetic field moves in a _____ direction.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 6.

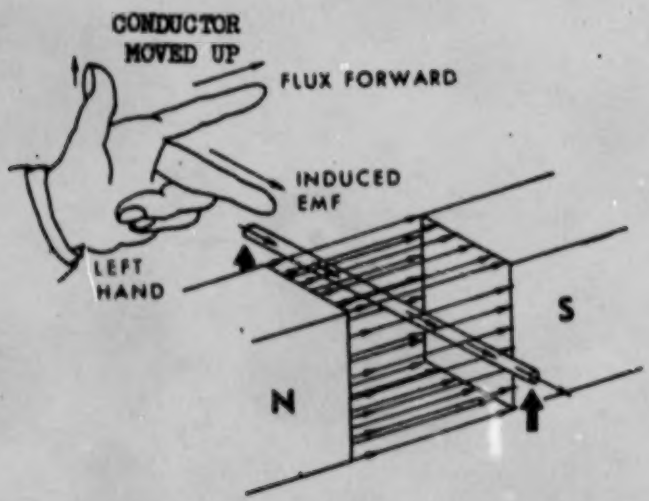
1041

CORRECT RESPONSES TO FRAME 6: 1. T, 2. T.

CORRECT RESPONSES TO FRAME 7: 1. zero maximum, 2. Windings, stator poles, 3. B-B', 4. clockwise.

Frame 8

Current flow is induced into the rotor by the magnetic field of the stator. You must know the direction of the induced current to determine which direction torque is applied to the rotor. The direction of induced current can be found IF the direction of conductor motion and the direction of the magnetic field are known. This is done by using the LEFT HAND GENERATOR RULE. The rule states "using your left hand, extend your thumb, index and middle fingers at right angles to one another. (See illustration). Position your hand with the thumb pointing in the direction of conductor motion. Point the index finger in the direction of magnetic lines of force (north to south). Your middle finger will point in the direction of induced current flow.



In the response sheet mark the following statements (T) true or (F) false.

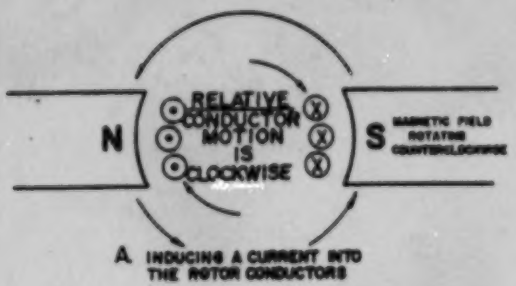
1. The left hand generator rule will give you the direction of conductor motion.

2. Current flow is induced into the rotor.

3. The direction of induced current can be found by using the left hand generator rule.

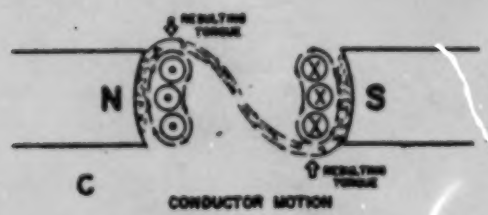
CHECK YOUR RESPONSES AT THE TOP OF PAGE 8.

The illustration shows you how current is induced into the rotor. The figures A, B, and C show the CONDUCTORS of the rotor between the north and south poles of the stator. The magnetic field of the stator is rotating counterclockwise. Remember the stator does notmove, the magnetic field moves. Motion of the rotor conductor RELATIVE to the stator field is CLOCKWISE (figure A). Use the left hand rule. The conductors on the LEFT are moving UP relative to the stator field. Point the thumb of your left hand toward the top of the page. Point the index finger in the direction of the stator field (north to south). Your middle finger will show that current flow in the LEFT conductors is toward you. Motion of the RIGHT conductors is toward the BOTTOM of the page. Point your left thumb toward the bottom of the page with the index finger pointing from north to south on the stator field. Your middle finger will show current flow into the page. Current flow in the rotor will cause the stator field to move as shown in figure C. Because the rotating magnetic field and torque are in the same direction the rotor will follow the rotating magnetic field of the stator.



A. INDUCING A CURRENT INTO THE ROTOR CONDUCTORS

B



C

CONDUCTOR MOTION

In the response sheet mark each statement either (T) true or (F) false.

1. In figure A relative conductor motion is clockwise because the magnetic field is moving counterclockwise.

2. Torque is in the same direction as the rotating magnetic field.

3. Using the left hand generator rule the thumb is pointed in the direction of conductor motion.

4. The stator conductors turn between the poles of the rotor.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 8.

1043

CORRECT RESPONSES TO FRAME 8: 1. F, 2. T, 3. T.

CORRECT RESPONSES TO FRAME 9: 1. T, 2. T, 3. T, 4. F.

Frame 10

For induction to take place the rotating magnetic field must move faster than the rotor. This is because the magnetic field of the stator must pass through the rotor conductors to induce current. IF the rotor was turning at the same speed as the stator field the conductors and lines of force would be aligned and no induction could take place. The magnetic field of the stator always sweeps through the rotor conductors slightly faster than rotor speed. This induces current into the rotor which in turn develops torque. The difference between the speed of the rotating magnetic field and the speed of the rotor is called SLIP.

Fill in the missing information in the response sheet for the following statements.

1. The magnetic field of the stator must move _____ than rotor speed.

2. Inducing current into the rotor produces _____.

3. Difference between the speed of the stator field and rotor speed is called _____.

4. Inducing current into the rotor the stator field must turn _____ than the _____.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 10.

Frame 11

It was stated in earlier frames that AC induction motors may operate on single two- or three-phase power. Two- and three-phase motors have a rotating magnetic field, because the phases are connected to different sets of stator poles. Remember, each phase is an independent power source. The two-phase motor has power 90 degrees out-of-phase. The three-phase motor has power 120 degrees out-of-phase. What about single-phase motors? There is no phase difference with single-phase power. A motor which operates on single-phase power is not self starting. It DOES NOT have a rotating magnetic field. Operation of a single-phase motor is accomplished by connecting the internal wiring of the motor in different ways. How this is done will be discussed in the following frames.

In the response sheet mark the following statements (T) true or (F) false.

1. A single-phase motor is not self starting.

2. The phases of two-phase power are 90 degrees apart.

3. Single-phase power is phased 120 degrees apart.

4. Operation of a single-phase motor is by connecting the wiring of the motor in different ways.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 10.

Review Frame 12

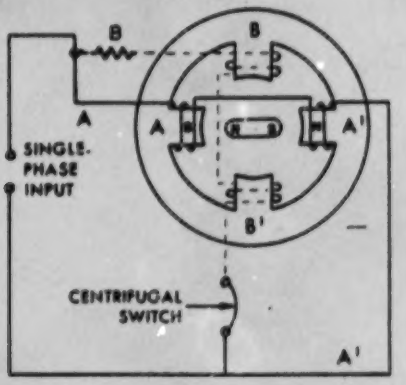
Match the items listed in column A with those listed in column B. Mark your answer in the response sheet.

Column A		Column B	
1.	Rotor	A.	Has no rotating magnetic field.
2.	Stator	B.	Has AC power applied.
3.	Single-phase motor	C.	Has AC power induced.
4.	Slip	D.	Difference in rotor and stator speed.
5.	Torque	E.	Is applied to the rotor.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 10.

Frame 13

As stated in frame 11 a motor which operates on single-phase power is not self starting. Because of this a single-phase motor is designed to operate like a two-phase motor. This is accomplished by connecting an auxiliary (starting) winding in parallel with the main (running) winding. Look at the illustration. The main winding is labeled A and A1, the auxiliary winding is labeled B and B1. Dotted lines identify the auxiliary winding. Notice the centrifugal switch located in the motor starting circuit. A motor with this type of connection is called a split-phase motor. The auxiliary winding may be connected permanently or disconnected by the centrifugal switch, after the motor has started running. As stated in previous frames an out-of-phase condition is required to produce a rotating magnetic field. In a split-phase motor the out-of-phase condition is obtained in several ways. In the illustration the out-of-phase condition is obtained by placing high resistance in the auxiliary (startin winding and high inductance in the main (running) winding. While the motor is starting both windings will have current flow. The centrifugal switch will disconnect the auxiliary winding at approximately 75% of motor speed. After the motor has started the force of the turning rotor will maintain motor operation.



Fill in the missing information for the following statements in the response sheet.

1. The auxiliary winding may be disconnected by a _____ _____.
2. The auxiliary winding may also be called a _____ winding.
3. The main winding is sometimes called the _____ winding.
4. A motor connected in parallel is called a _____ _____ motor.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 10.

1045

CORRECT RESPONSES TO FRAME 10: 1. faster, 2. torque, 3. slip, 4. faster, rotor.

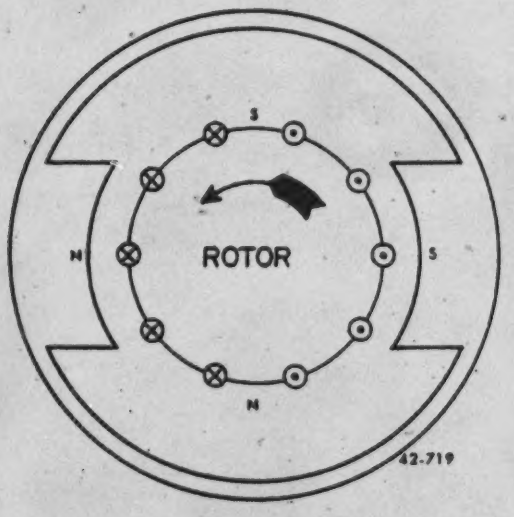
CORRECT RESPONSES TO FRAME 11: 1. T, 2. T, 3. F, 4. T.

CORRECT RESPONSES TO FRAME 12: 1. C, 2. B, 3. A, 4. D, 5. E.

CORRECT RESPONSES TO FRAME 13: 1. centrifugal switch, 2. starting, 3. running, 4. split phase.

Frame 14

In our discussion of AC motors, the rotor is moved by two forces. The force of the rotating magnetic field (frame 7) and the torqueing action as the magnetic field around the rotor conductors act on the stator field (frame 9). At this point we will discuss a THIRD force which will make the rotor turn. As stated earlier when the rotor turns it has current induced into it. This will cause the entire rotor to be magnetized. The magnetic field of the rotor will be in a position that will cause the rotor field to be attracted to the stator field. The illustration shows the magnetic field of the rotor with the south pole at the top and north at the bottom. The south pole of the rotor will be drawn to the north pole of the stator. The north pole of the rotor is pulled toward the south pole of the stator. The magnetic field of the rotor always remains in a fixed position. The rotor and stator poles will never become aligned. Although the poles will never align themselves the force which will cause them to try is present in the rotor.

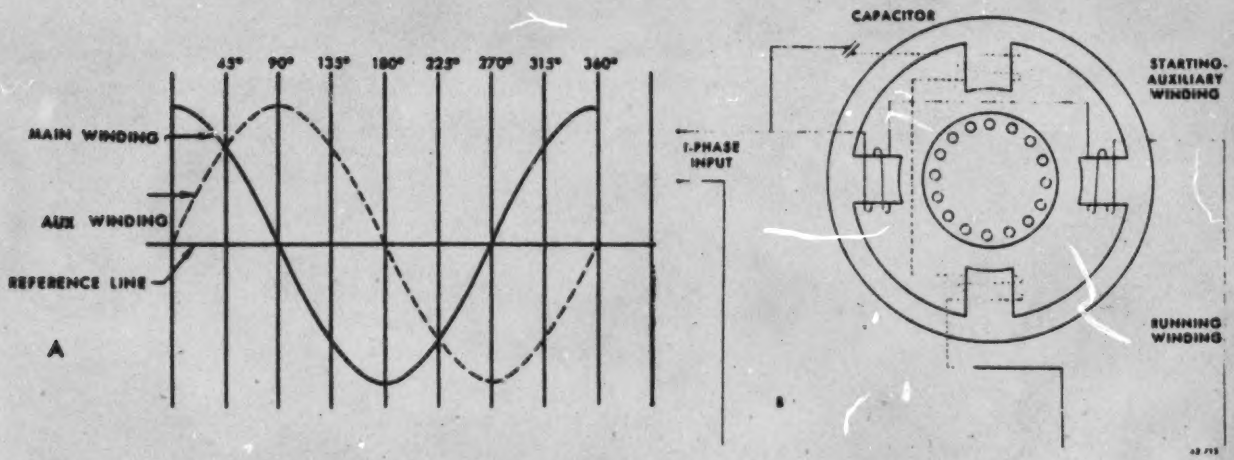


Mark the following statements (T) true or (F) false in the response sheet.

1. The rotor of AC motor will be magnetized.
2. The rotor field will be aligned with the stator field.
3. The rotor is acted upon by three forces.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 12.

A motor with a resistance in the starting winding doesn't have a high starting torque. This is because the resistance does not create a very large phase difference between the current flow in the starting winding and current flow in the running winding. Where a higher starting torque is needed, a motor with a capacitor wired in the starting circuit is often used (figure B). This circuit arrangement will cause the current in the starting winding to lead the current in the running winding (figure A). As a result a two-phase EFFECT is achieved. There is more of a difference between the phases in this type of motor than one with resistance in the starting windings. Because of the phase difference a higher torque will result.



Fill in the missing information for the following statements in the response sheet.

1. More starting torque is obtained by connecting a _____ in the starting winding.

2. A capacitor is connected in the motor to achieve higher _____ _____.

3. In a split-phase AC motor a _____ phase effect is obtained.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 12.

1047

CORRECT RESPONSE TO FRAME 14: 1. T, 2. F, 3. T.

CORRECT RESPONSE TO FRAME 15: 1. capacitor, 2. starting torque, 3. two.

Frame 16

The AC motor most often used in environmental systems is the reversible AC motor. Reversible single-phase motors will be equipped with two stator windings. Supplying power to one winding will cause the motor to turn clockwise. Applying power to the other winding will turn the motor counter-clockwise. In the reversible type motor the centrifugal switch is not used and the starting and running windings are permanently connected.

Mark the following statements (T) true or (F) false in the response sheet.

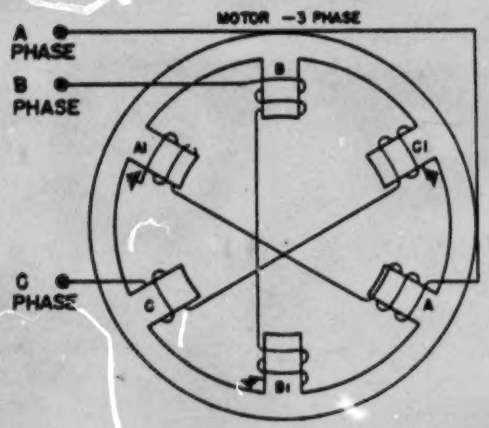
1. A reversible single-phase AC motor is equipped with two stator windings.

2. A reversible AC motor uses two centrifugal switches.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 14.

1069

In places where high starting torque and relatively quiet operation is needed a three-phase motor is used. The rotating magnetic field of a three-phase motor creates a more constant torque than the fields of split and two-phase motors. This is because more motor poles are receiving power at a given time. Other than that the operation of a three-phase motor is very much like a two-phase motor. The illustration will show you how a three-phase motor is connected electrically. Notice that there are three seperate paths for current flow to three sets of motor poles.



NO RESPONSE REQUIRED

1049

CORRECT RESPONSES TO FRAME 16: 1. T, 2. F.

CORRECT RESPONSES TO FRAME 17: None Required.

Frame 18

The illustration shows the rotating magnetic field of a three-phase AC motor. Figure 6 of the illustration shows phase A connected to poles A and A1, phase B to poles B and B1, and phase C to poles C and C1. Using figure 1 as a guide and comparing it to figures 2 through 5 the figures will show how a rotating magnetic field is achieved. Point w of figure 1 shows phases A and B at near maximum value while phase C is at zero. The magnetic lines of force are as shown in figure 2. The rotating magnetic field will be moving counterclockwise. Now move down the time line (figure 1) to point 3. At point 3, phase A is at zero and phases B and C are near maximum. This will cause the magnetic field to rotate counterclockwise to the position shown in figure 3. Compare points 4 and 5 (figure 1) and figures 4 and 5 and notice how the field continues to rotate counterclockwise. A check of points 2 and 5 (figure 1) and figures 2 and 5 will show that both current and the magnetic poles of the motor have changed polarity. Point 6 is the place where the motor will complete 360 degrees rotation. The current values of point 6 are the same as they were at point 2.

Mark the following statements (T) true or (F) false in the response sheet.

1. The current values at points two and six of figure 1 are the same.

2. The magnetic poles of the motor will change polarity as the current changes polarity.

3. From point two to point six the motor makes one complete turn.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 16.

1071

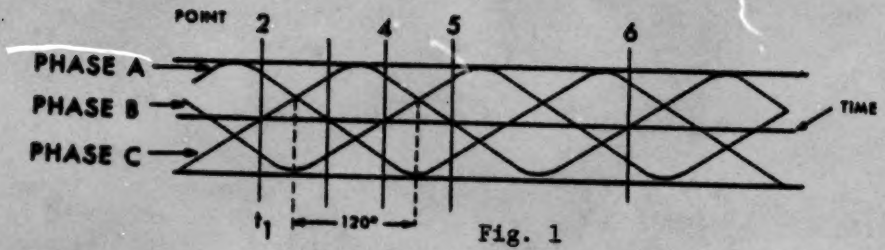


Fig. 1

Fig. 2

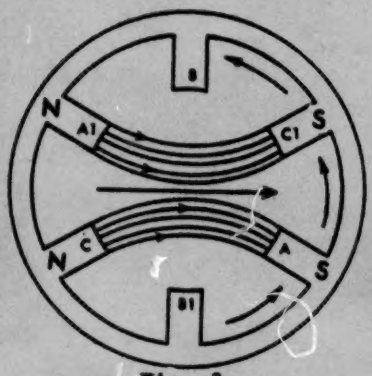


Fig. 3

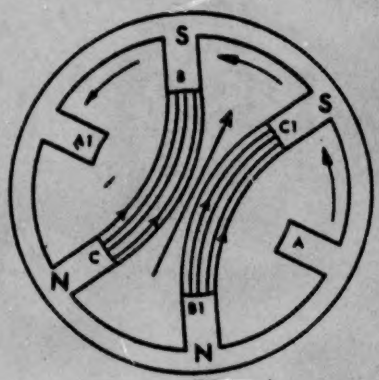


Fig. 4

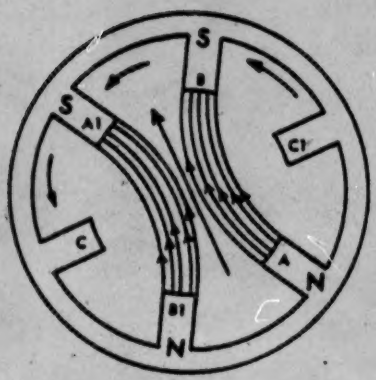


Fig. 5

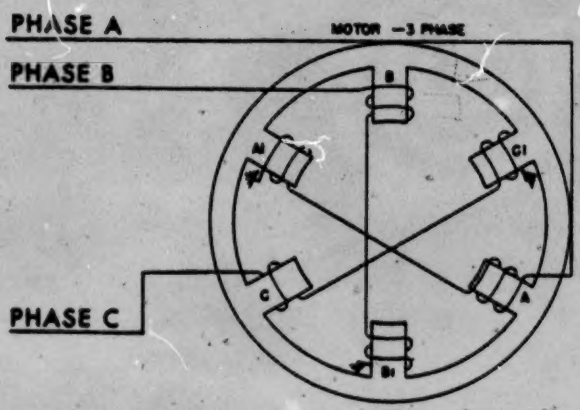


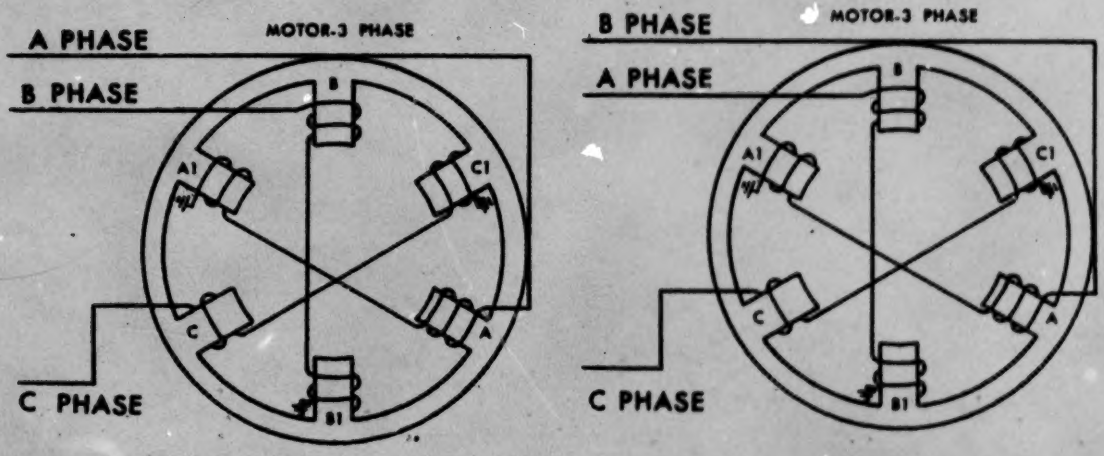
Fig. 6

1051

CORRECT RESPONSE TO FRAME 18: 1. T, 2. T, 3. T.

Frame 19

A single-phase motor is reversed by using two stator windings. Reversing a three-phase motor is done differently. The direction of rotation of a three-phase motor is reversed by reversing the connections on any tow of the three phases. The illustration shows you two AC motors. These two motors will turn in opposite directions because A and B phases have been reversed on the right hand motor. Reversing the phases will reverse the direction of the rotating magnetic field and also motor direction. Reversing a three-phase motor is done using a relay circuit which you will study in your next text.



Fill in the missing information for the following statements in the response sheet.

1. Reversing two phases of a three-phase motor will change the direction of the _____ _____ field.

2. Reversing a three-phase motor can be done using a _____ circuit.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 18.

1073

The rotor of an induction motor turns at a slower speed than the rotating magnetic field of the stator. The difference in speed is called SLIP. Slip is necessary in an induction type motor because if the rotor turned at the same speed as the rotating magnetic field no current would be induced. The speed of the rotating magnetic field is called SYNCHRONOUS SPEED. An AC motor which is designed to turn at the same speed as the rotating field of the stator is called a synchronous motor. A synchronous motor is used where exact speed regulation is necessary. The ROTOR of a synchronous motor is made of permanent magnets or is magnetized from an outside DC power source. Because the north and south poles of the rotor do not change the rotor will turn at synchronous speed. The speed of a synchronous motor is proportional to the AC frequency. The motor can be used to drive precision units if frequency is closely adjusted.

Mark the following statements (T) true or (F) false in the response sheet.

1. The difference between the speed of the rotor and the speed of the rotating magnetic field is called SLIP.

2. The rotor of a synchronous motor can be made of permanent magnets.

3. The speed of the rotating magnetic field is called induction.

CHECK YOUR RESPONSES AT THE TOP OF PAGE 18.

1053

CORRECT RESPONSES TO FRAME 19: 1. rotating magnet, 2. relay.

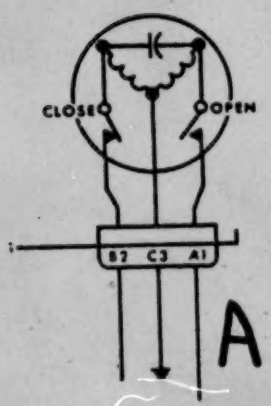
CORRECT RESPONSES TO FRAME 20: 1. T, 2. T, 3. F.

CORRECT RESPONSES TO FRAME 21: None Required.

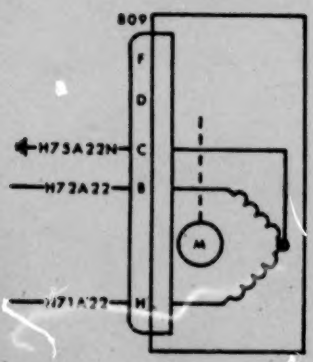
Frame 21

The illustration will show you how several different types of AC motors will appear on a wiring diagram. Figure A shows a reversible single-phase motor. Figure B is a two-phase motor. The two figures marked C and D are two methods of wiring a three-phase motor. The three-phase motor is generally equipped with a ground wire to prevent electrical shocks but it is not necessary for motor operation.

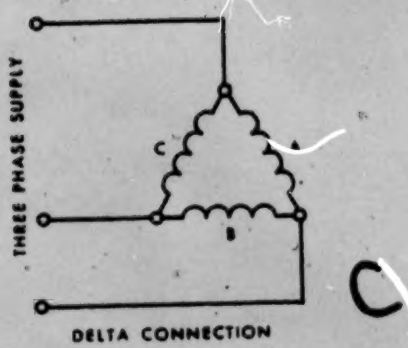
NO RESPONSE REQUIRED



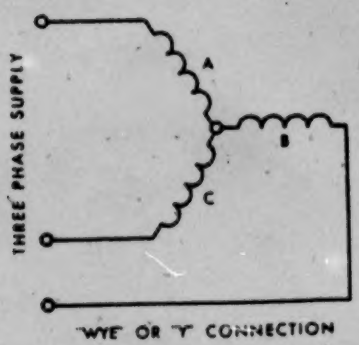
A



B



C



D

END OF TEXT 1075

WORKBOOK
3ABR42331-WB-126

Technical Training

Aircraft Environmental Systems Mechanic

AC MOTORS AND CONTROL CIRCUITS WIRING DIAGRAM

5 February 1979

CHANUTE TECHNICAL TRAINING CENTER (ATC)
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Chanute Air Force Base, Illinois

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Environmental Pneudraulics Branch
Chanute AFB, Illinois

3ABR42331-WB-116

AC MOTORS AND CONTROL CIRCUITS WIRING DIAGRAM

OBJECTIVES

Using an electrical diagram, identify a minimum of 8 out of 10 circuit malfunctions, when given the cause and circuit conditions.

EQUIPMENT

	Basis of Issue
Colored Pencil Set	1/student

PROCEDURE

Pay close attention to all directions that you are given in the workbook. When performing in the workbook, such as tracing or solving problems, if your response is incorrect, restudy the information. At the end of this workbook, you will have a progress check which will be graded by your instructor. If you are ready to begin and have no questions, proceed with the lesson.

In this section you will become familiar with an AC circuit as shown in figure 1, page 24 in Part 3 of this workbook. It is designed to operate and reverse the operation of single phase and three phase motors. You will learn this by tracing the individual circuits which make up the entire circuit. Let us begin by discussing the system's switches.

The three (3) switches in the circuit which control the body crossover manifold valve and strut #3 bleed valve are the manifold valve switch, master switch and bleed selector switch. The two (2) switches in the circuit which control the open and close control relays, used to control the modulating valve, are the master switch and the manual switch. You will use this workbook, Parts 1, 2, and 3, to complete the lesson objectives.

Part 1 consists of instructions and confirmations. Part 2 consists of figures and foldouts. Begin with Exercise 1.

Note: You may remove Part 3 from Part 2 for ease of tracing if you so desire.

Supersedes 3ABR42231-WB-116, 19 August 1977.
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PART 1

Exercise 1

In this exercise, we will trace power to the manifold valve switch. You will use a red pencil and figure 1 in Part 3 of this workbook.

1. Trace from Point A on the 118-205V, three phase, 400 Hertz AC bus bar, to the junction point of wires H200A20 and H400A20. Keep in mind that both wires use the same circuit breaker. For the time being we will trace only H200A20.

2. Trace up wire H200A20 to the manifold valve switch-pole A and the jumper wires to poles B and C. You have now applied power up to the manifold valve switch.

3. Turn to page 14 in Part 2 for confirmation. If you have traced this correctly, transfer what you have traced to foldout 1 in Part 3 of this workbook.

Exercise 2

In this exercise, we will trace the manifold valve switch in the open position. You will use a dark green pencil and figure 1 in Part 3 of this workbook.

1. Draw the manifold valve switch to the open position, by moving the armature of the switch down to Points 2 and 4. Notice the broken line between the two contacts. This indicates that the armatures are joined together by a single switch. If one armature moves, the other moves, in the same direction at the same time. This allows us to control two or more paths of current flow with a single switch.

2. Trace from Point 2, across wire H220A20 to Point 1 on the bleed selector switch.

3. Trace along wire H220B20 to pin B of the body crossover manifold valve connector plug. Remember this is a single phase AC motor. It has a capacitor start winding. In order to apply power to the motor correctly, we must trace it in the following manner.

4. Trace from pin B of the body crossover manifold valve connector plug, to the microswitch (open). Draw the microswitch closed.

5. Trace from the microswitch up to the capacitor.

6. Trace through and to the other side of the capacitor. You have now applied power to both windings.

7. Trace through both windings and out to Pin C of the valve.

8. Trace from Pin C down wires H310B20N, H310D20N and along H310E20N and on out to ground on the bus bar.

9. Go back to Point 4 of the manifold valve switch. Trace from this point along wire H240A20 to Point 4 of the bleed selector switch.

10. Trace from the bleed selector switch to Pin B of the strut #3 bleed valve connector plug.

11. Remember this is a single phase motor. You must trace it in the same manner as you did the body crossover manifold valve. Trace the capacitor and the windings and on out Pin C.

12. Trace from Pin C on out to ground at the bus bar. You will notice that wire H310D20N and H310E20N ground wires are shared by both single phase AC valves.

13. The body crossover manifold and strut #3 bleed valve are now open. Also, notice, with the manifold valve switch in the open position, the master switch and bleed selector have been bypassed. Turn to page 15 in Part 2 of this workbook for confirmation. If you have traced this correctly, transfer what you have traced to foldout 1 in Part 3.

Exercise 3

Now we will look at the manifold valve switch in the closed position. You will use a dark blue pencil and figure 2 in Part 3 of this workbook.

1. Draw the manifold valve switch armature(s) to the closed position.

2. Trace from Point 1 to pole A and stop.

3. Trace from Point 3 to pole B and stop.

4. With the manifold valve switch in the closed position, power is supplied to the master switch. This switch has two positions, RAM or up position and PRESSURE or down position. This switch is also made, so that if one armature moves, all three armatures move.

5. Trace the master switch in the RAM position as shown.

6. Trace from pole A to Points 1 and 2, and then over to Point 3 of the bleed selector switch.

7. Trace down and over to Pin A of the strut #3 bleed valve connector plug.

8. Trace through the microswitch (closed), windings, capacitor and on out Pin C of the valve.

9. Trace from Pin C to the ground on the bus bar. This valve will now close.

10. Trace from pole B of the master switch to Points 5 and 6 of the master switch.

11. Trace from Point 6 of the master switch to Point 2 of the bleed selector switch.

12. Trace from Point 2 of the bleed selector switch to Pin A of the body crossover manifold valve.

13. Trace through the valve, in the same manner as you did the strut #3 bleed valve, to Pin C of the body crossover manifold valve.

14. Trace from Pin C to ground on the bus bar. You will notice the H310D20N and H310E20N are again shared by both valves.

15. This valve is now closed. Remember, with the manifold valve switch in the closed position, the master switch in the RAM position, the bleed selector switch has been bypassed.

16. Turn to page 16 for confirmation in Part 2.

17. If you have traced this exercise correctly, transfer what you have traced to foldout 1 in Part 3 of this workbook.

Exercise 4

Let us see what will happen with the master switch in the PRESSURE position. You will use an orange pencil and figure 3 in Part 3 of this workbook.

1. Draw the manifold valve switch to the closed position.

2. Draw the armature of the master switch to the PRESSURE (down) position.

3. Trace from Point 1 of the manifold valve switch to the master switch pole A.

4. Trace through the master switch to the bleed selector switch.

5. Trace through the bleed selector switch to Pin B of the body crossover manifold valve.

6. Trace through the valve and windings to Pin C of the valve.

7. Trace from Pin C to ground on the bus bar.

8. Go back to Point 3 of the manifold valve switch and trace from there to the master switch.

9. Trace from the master switch to the bleed selector switch.

10. Trace through the bleed selector switch to Pin A of the strut #3 bleed valve.

11. Trace through the valve and windings, and out to ground on the bus bar.

12. You can see, with the master switch in the PRESSURE position, power is always applied to the close side of the strut #3 bleed valve, to insure that the valve stays closed.

13. Turn to page 17 for confirmation in Part 2.

14. If you have traced this exercise correctly, transfer what you have traced to foldout 1 in Part 3 of this workbook.

Exercise 5

The bleed selector switch in figure 4 in Part 3 of this workbook is shown in the normal position. Let us see what will happen when you place the bleed selector switch in the alternate position. You will use a light blue pencil and figure 4 in Part 3 of this workbook.

1. Trace the manifold valve switch in the closed position.

2. Trace the master switch to the PRESSURE position.

3. Trace the bleed selector switch to the alternate position.

4. Trace from Point 1 on the manifold valve switch to the master switch.

5. Trace through the master switch to the bleed selector switch.

6. Trace through the bleed selector switch to Pin A of the body crossover manifold valve connector plug.

7. Trace from Pin A through the valve and windings to Pin C of the valve.

8. Trace from Pin C to the ground on the bus bar.

9. Go back to Point 3 of the manifold valve switch and trace from there to the master switch.

10. Trace through the master switch to the bleed selector switch.

11. Trace through the bleed selector switch to Pin B of the strut #3 bleed valve connector plug.

12. Trace through the valve and windings and to Pin C of the valve.

13. Trace from Pin C out to the ground at the bus bar.

14. This will cause the body crossover manifold valve to close and the strut #3 bleed valve to open.

15. Turn to page 18 for confirmation in Part 2.

16. If you have traced this exercise correctly, transfer what you have traced to foldout 1 in Part 3 of this workbook.

Note: Before we continue, let's take a look at the ground wire for the body crossover manifold valve and the strut #3 bleed valve. If H310B20N is broken, only the body crossover manifold valve won't work. If H310C20N is broken, only the strut #3 bleed valve will not work. Each wire is common only to that valve. However, if H310D20N or H310E20N is broken, neither valve will work.

Exercise 6

You have learned that the master switch has three armatures. You have already traced wiring for two of these armatures. Let's now trace the wiring that is connected to the third armature. You will see that this armature allows 28V DC power to go to the manual switch, which in turn controls the relay(s) and the relay(s) control the 3 phase modulating valve. You will also learn where the power for the three phase motor comes from. For this exercise, you will use a brown and a red pencil and figure 4 in Part 3 of this workbook.

1. With a brown pencil, trace the master switch to the PRESSURE position. Remember all three armatures move down at the same time.

2. With a brown pencil, trace from the positive connection of the 28V DC bus bar to pole C of the master switch.

3. With a brown pencil, trace through the switch and down to the manual switch and stop.

4. Go back to the AC bus bar.

5. With a red pencil, trace from circuit breaker A to pole B2 of the open relay.

6. With a red pencil, trace through armature (B2-B3) to Point B3 of the close relay.

7. With a red pencil, trace from circuit breaker B of the bus bar to pole C2 of the open relay.

8. Trace through armature (C2-C3) to Point C3 of the close relay.

9. Trace from circuit breaker C to pole D2 of the open relay.

10. Trace through armature (D2-D3) to Point D3 of the closed relay.

11. Turn to page 19 for confirmation in Part 2.

12. If you have traced this exercise correctly, transfer what you have traced to foldout 1 in Part 3 of this workbook.

13. Let's go back and review what you have just traced. As you have already seen, the power for the manual switch is 28V DC. The manual switch controls the open and close relays, which in turn control the modulating valves three phase motor. Power for the three phase motor comes from the 3 phase AC bus bar. This 3 phase control circuit is now ready for a signal. This signal will cause the 3 phase modulating valve to open or close. The manual switch controls this signal.

Exercise 7

We are now going to trace the circuit that will close the modulating valve. You will use a light green pencil and figure 4 in Part 3 of this workbook.

1. Draw the manual switch to the closed position. Remember, in Exercise 6 you traced power to the manual switch in brown.

2. Trace from the manual switch to Pin F of the modulating valve.

3. Trace from Pin F, through the close limit switch, to Pin E of the modulating valve.

4. Trace from Pin E to X1 of the close relay.

5. Trace from X1 to X2 of the close relay coil.

6. Trace from X2 to ground on the negative point of the 28V DC bus bar.

7. Draw the three armatures of the close relay to the energized (down) position.

8. Trace phase A from Point B1 of the close relay to Pin A of the modulating valve connector plug.

9. Trace through the valves AØ (phase) winding to Pin H of the modulating valve.

10. Trace from Pin H to ground on the bus bar.

11. Go back to the relay and trace phase B from Point C1 to Pin B of the modulating valve.

12. Trace through the valves BØ winding and on out to ground at the bus bar.

13. Start again at the close relay and trace phase C from Point D1 to Pin G of the modulating valves connector plug.

14. Trace from Pin G through the valves CØ winding to Pin H and on out to the ground on the bus bar.

15. The modulating valve will now close, with all three phases of power applied.

16. Turn to page 20 for confirmation of what you have traced.

17. If you have completed this exercise correctly, transfer what you have traced to foldout 1 in Part 3 of this workbook.

Exercise 8

We will now see what will happen if the manual switch is in the open position. For this exercise, you will use a purple pencil and figure 5 in Part 3 of this workbook.

1. Draw the manual switch to the open position.

2. Trace from the manual switch to Pin D of the modulating valve.

3. Trace from Pin D of the modulating valve, through the open limit switch (insure that this limit switch had been traced to the closed position and the close limit switch to the open position) to Pin C of the modulating valve.

4. Trace from Pin C through the open relay coil to ground on the 28V DC bus bar.

5. The open relay is now energized.

6. Draw the armature of the open relay to the energized (down) position.

7. With this open relay energized, the close relay is de-energized. This is caused by the operation of the limit switches within the modulating valve. If you have forgotten limit switch operation, refer back to the wiring diagram on DC Motors workbook.

8. With the open relay energized, we can trace 3 phase power to the modulating valve. Trace phase A from Point B1 of the open relay to Point C1 on the close relay.

9. Trace from Point C1 of the close relay to Pin B of the modulating valve.

10. Trace through the motor BØ winding and out to the ground on the bus bar.

11. Go back to the open relay. Trace phase B from Point C1 to Point B1 of the close relay.

12. Trace from Point B1 of the relay to Pin A of the modulating valve.

13. Trace through the motor AØ winding and out to ground on the bus bar.

14. Go back to the open relay and trace phase C from Point D1 to Point D1 of the close relay.

15. Trace from Point D1 of the relay to Pin G of the modulating valve.

16. Trace through the motor CØ winding and out to ground on the bus bar.

17. The valve 3Ø motor will now go in the opposite direction and open. This is caused by reversing two phases of power to the motor windings. Phase A and B are reversed to the A and B phase motor windings on Pins A and B at the motor.

18. Notice the power direction when only the close relay is energized. The power leaves Point A of the AC bus bar and travels to Pin A of the modulating valve. The power that leaves Point B of the AC bus bar goes to Pin B of the modulating valve.

19. Also notice the direction of the power with only the open relay energized. The power that leaves circuit breaker A of the AC bus bar is now going to Pin B of the modulating valve, and the power from circuit breaker B is now going to Pin A of the valve. The CØ remains the same with either relay energized.

20. Turn to page 21 for confirmation of what you have traced in this exercise.

21. If you have traced this exercise correctly, transfer what you have traced to foldout 1 in Part 3 of this workbook.

Note: Another point to remember is that the modulating valve is a three phase motor. If you will recall from your AC Motor programmed text, a three phase motor does not require an external ground for motor operation. This means that even though all three phases are connected to ground wire H310A20N and in turn H310E20N, an open in either or both of these wires will have no effect on the operation of the modulating valve.

Note: Wire H300C20N is a ground wire shared by both open and close relay ground.

Now that you have traced the individual circuits, you should be ready to solve some circuit malfunctions.

Using foldout 2, figures 6 and 7, you will identify the circuit malfunction(s) in the AC Motor Control Circuit which are all caused by open circuit(s). You will place one or more "X's" in the block(s) which will give you the correct circuit malfunction. The first one has been done for you.

The second one you must do for practice and have it checked by your instructor before you proceed to the problems in the progress check. Keep in mind as you do each problem, you must mark only the malfunctions that directly relate to each problem.

PRACTICE PROBLEM 1

First look at figure 7 and find practice problem #1, then, using figure 6, look for problem #1 in the AC Motor Control Circuit. After you have found #1 on figure 6, you will see that it points to an open positive wire for both single phase valves. Remember that all the problems given in this exercise are open circuits.

1. Figure 7 gives you the answer sheet for practice problem #1.

2. Figure 6 gives you the location of the open circuit H200A20 the positive lead for both single phase motor valve assemblies.

Note: An "OPEN CIRCUIT" may be a condition of electrical circuit caused by the breaking of continuity of one or more of the conductors of the circuit; usually an undesired condition. It may also be a circuit which does not provide a complete path for current to flow.

3. Look at figure 6 and place the manifold valve switch, master switch, and the bleed selector switch in any combination of positions, you should then find that the body crossover manifold and strut number 3 bleed valve will not operate. You will also find that wire H200A20 is not used in any way to support the operation of the modulating valve. Now examine figure 7 and you will find how this problem number 1 has been marked for you.

If you have any questions on how this problem was marked, ask your instructor at this time.

PRACTICE PROBLEM #2

You should be able to complete this practice problem on your own in foldout 2. If you are not sure, consult your instructor at this time.

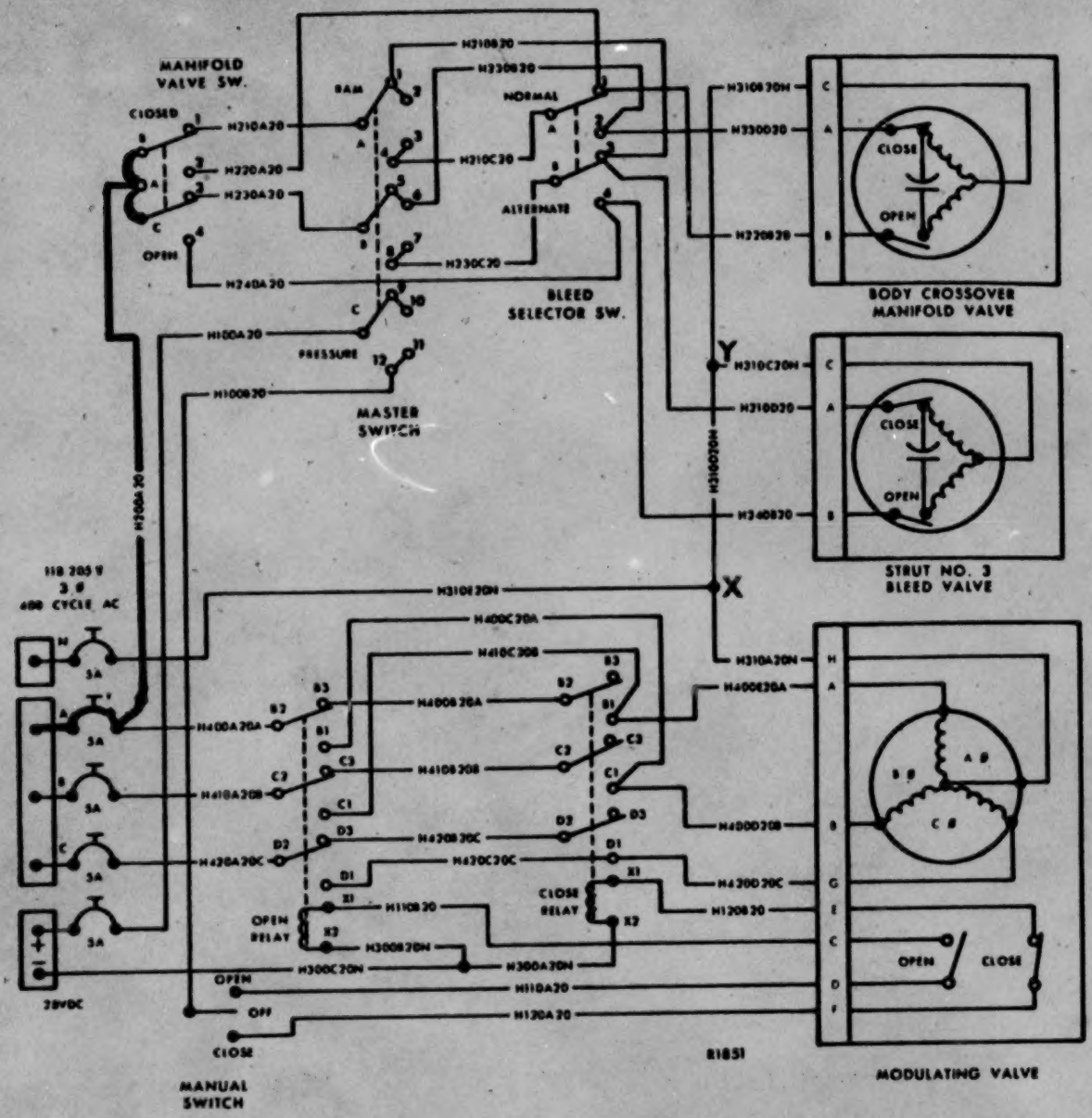
When you finish the practice problems, have them checked and signed off by your instructor before you progress.

PROGRESS CHECK

The next ten problems in foldout 2 will not be done any place but in the classroom and under the supervision of the instructor. You will not do these problems in the barracks or at home. You must identify a minimum of 8 out of 10 circuit malfunctions correctly. Your instructor must check your work after the first five problems. If your instructor says your work is satisfactory, he will initial your work allowing you to progress. If the instructor says it is unsatisfactory, it will not be initialed and you will follow the instructions of the instructor.

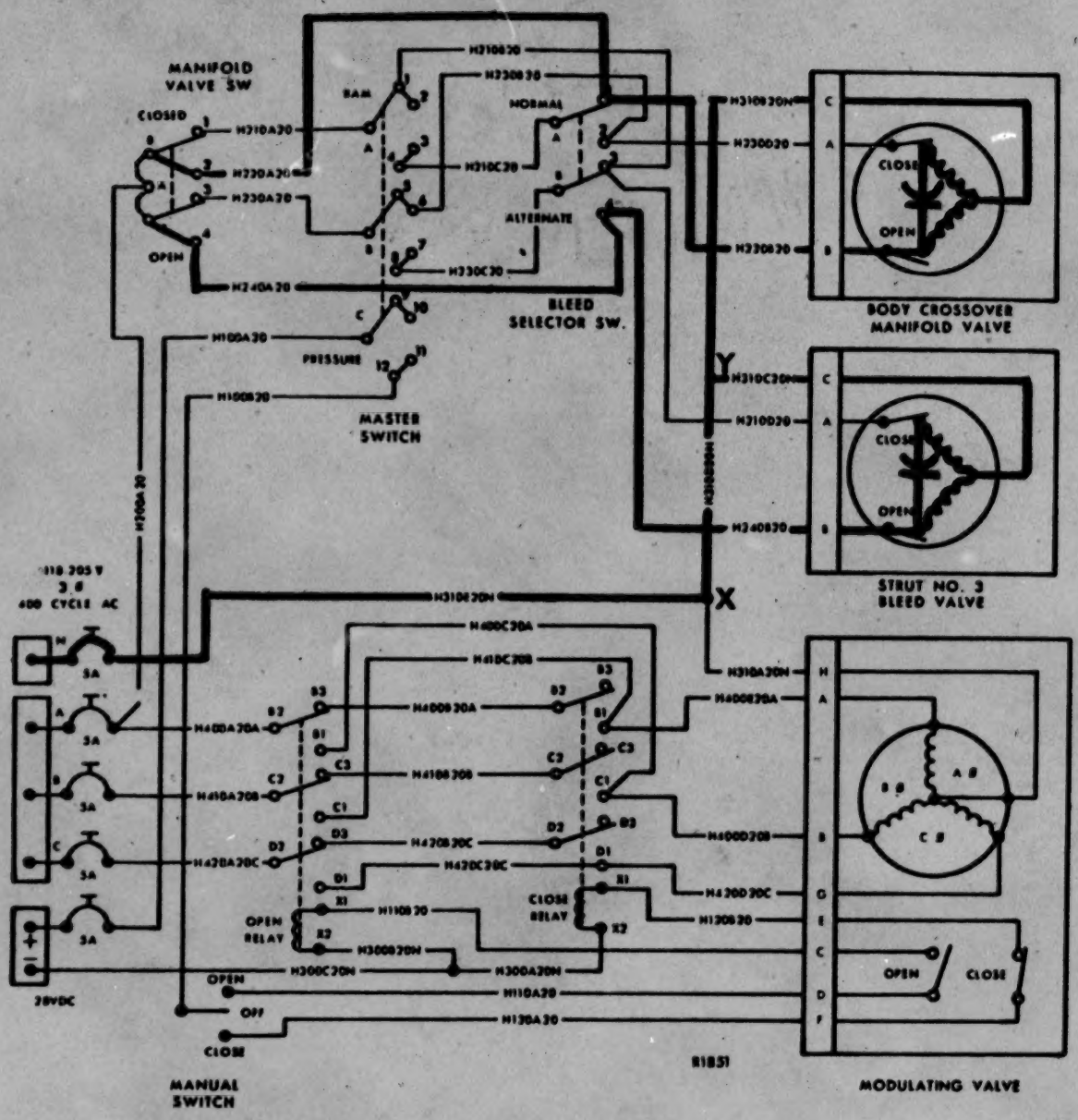
PART 2

Confirmation(s) for Exercises 1 through 8.



NOTE: The bold lines above are RED.

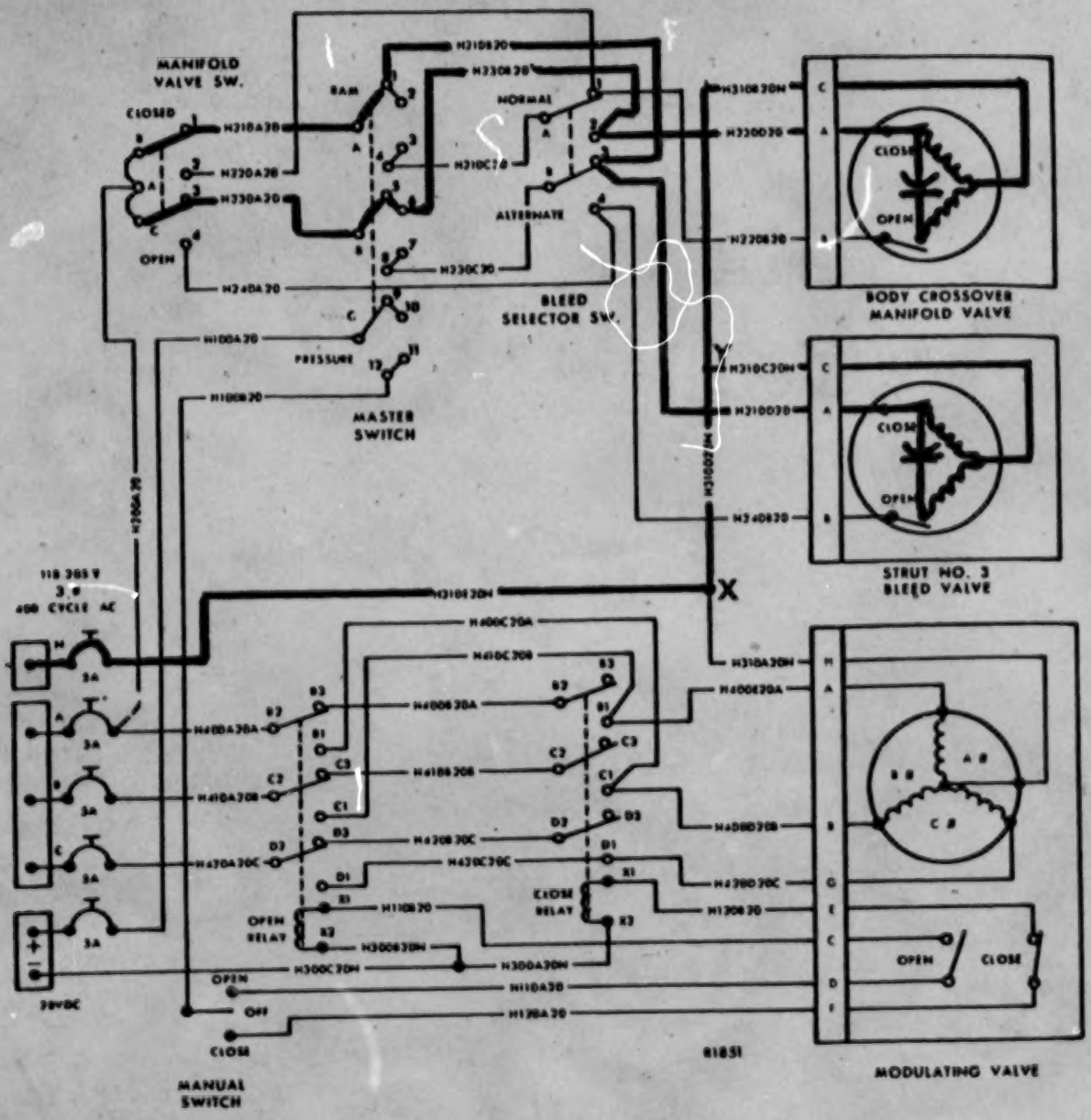
Part 2, Exercise 1 Confirmation.



NOTE: The bold lines above are DARK GREEN.

Part 2, Exercise 2 Confirmation.

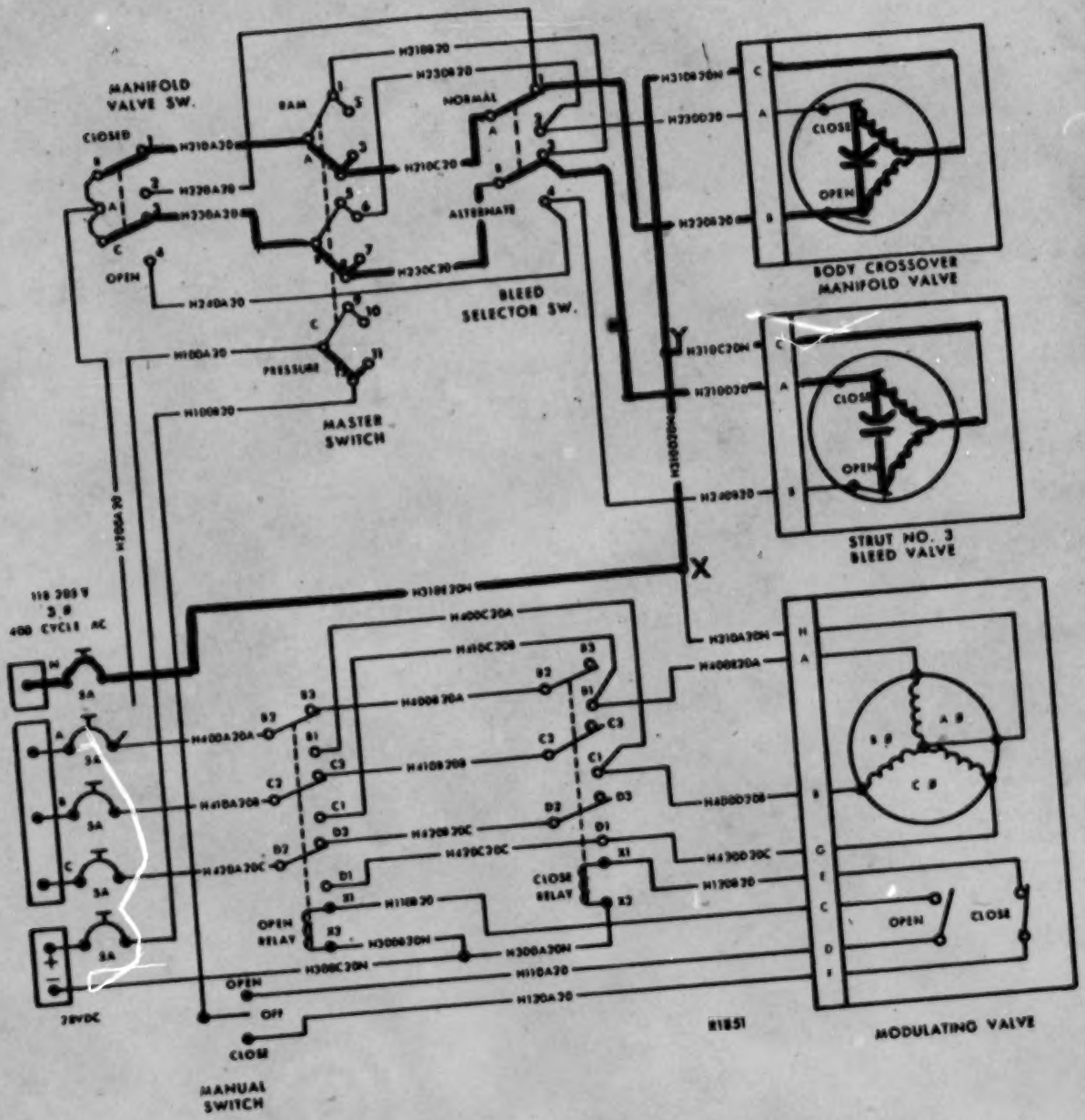
1069



NOTE: The bold lines above are DARK BLUE.

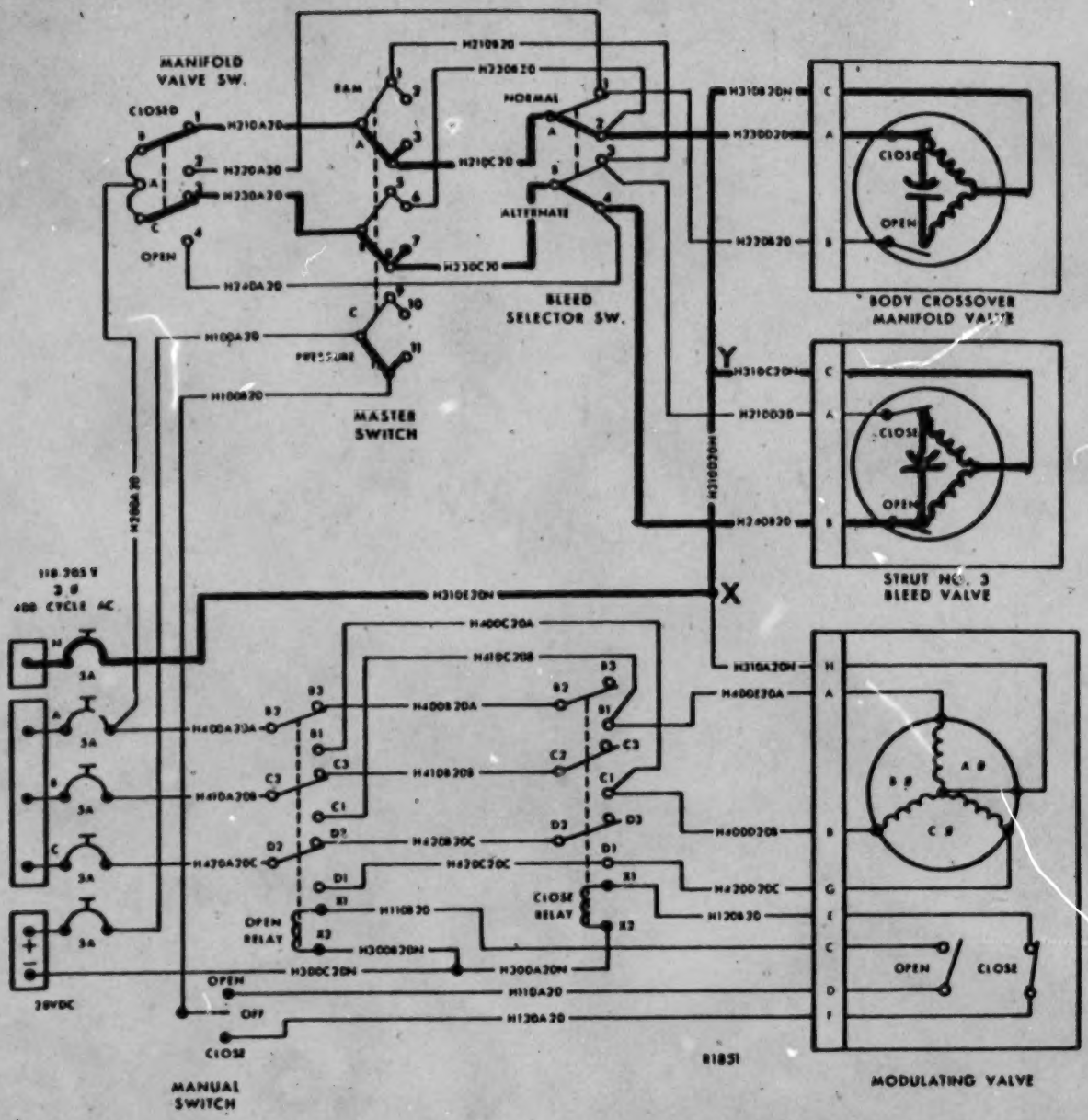
Part 2, Exercise 3 Confirmation.

1091



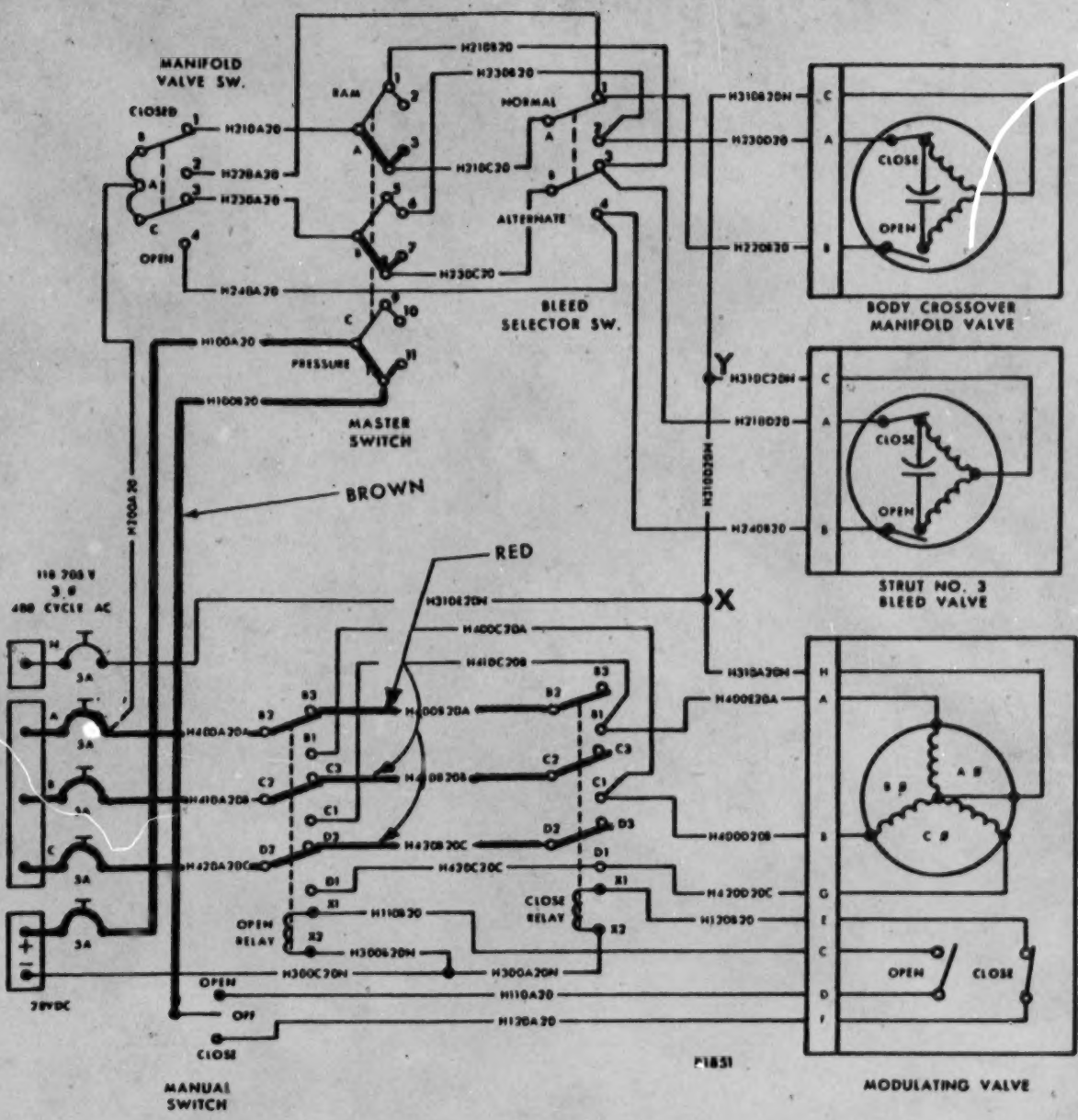
NOTE: The bold lines above are ORANGE.

Part 2, Exercise 4 Confirmation.



NOTE: The bold lines above are LIGHT BLUE.

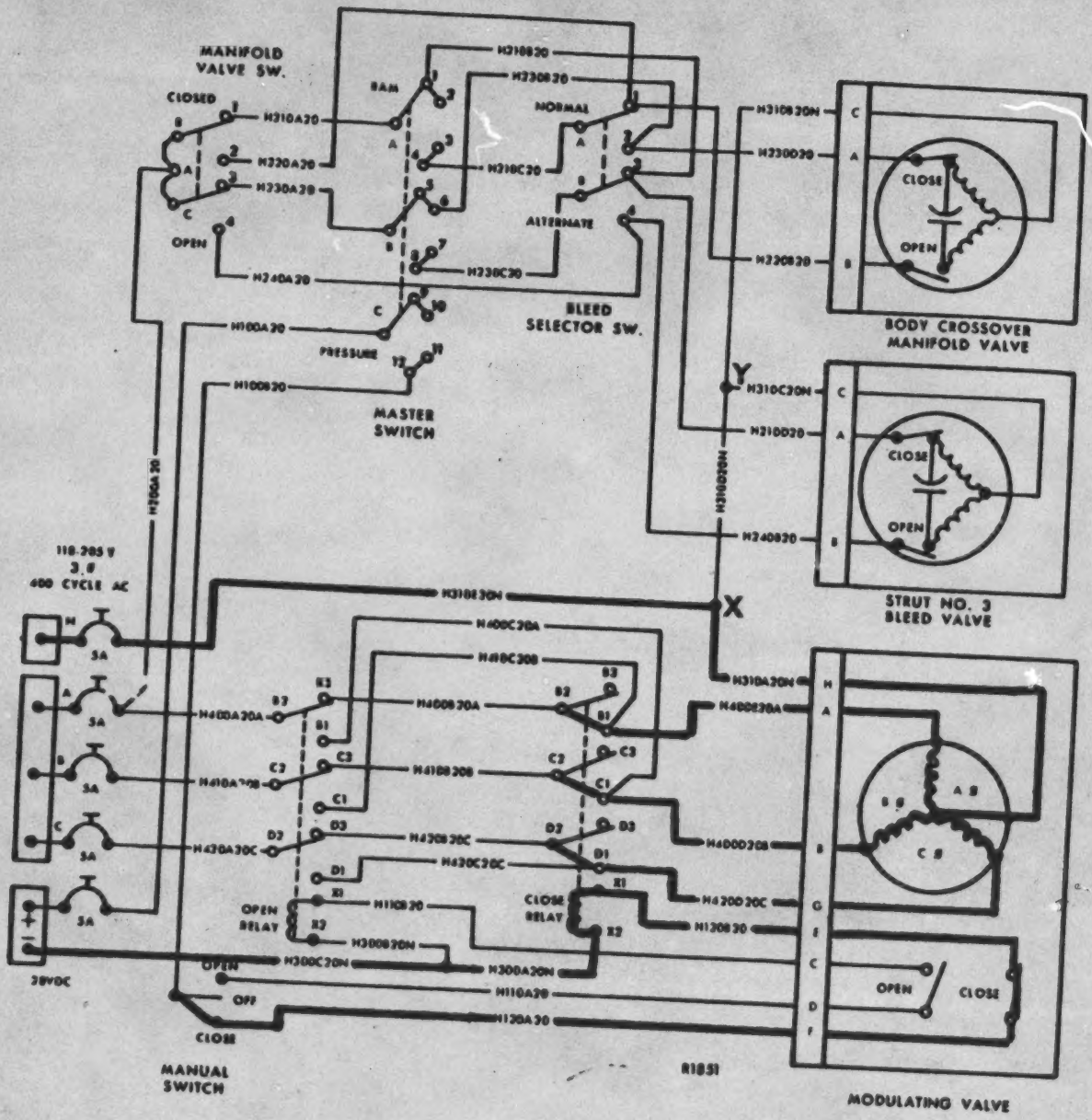
Part 2, Exercise 5 Confirmation.



NOTE: The above bold lines are BROWN and RED.

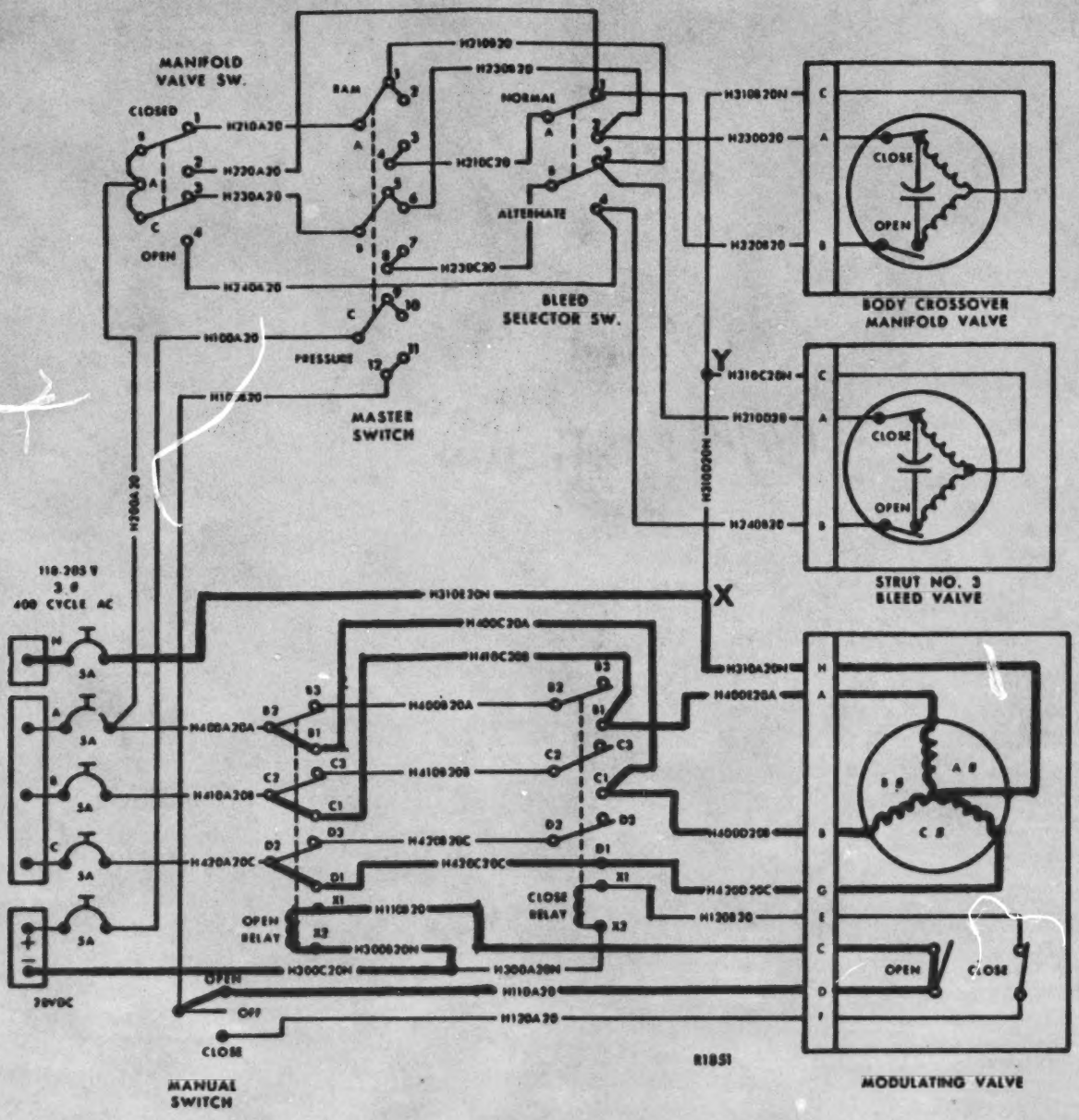
Part 2, Exercise 6 Confirmation.

1073



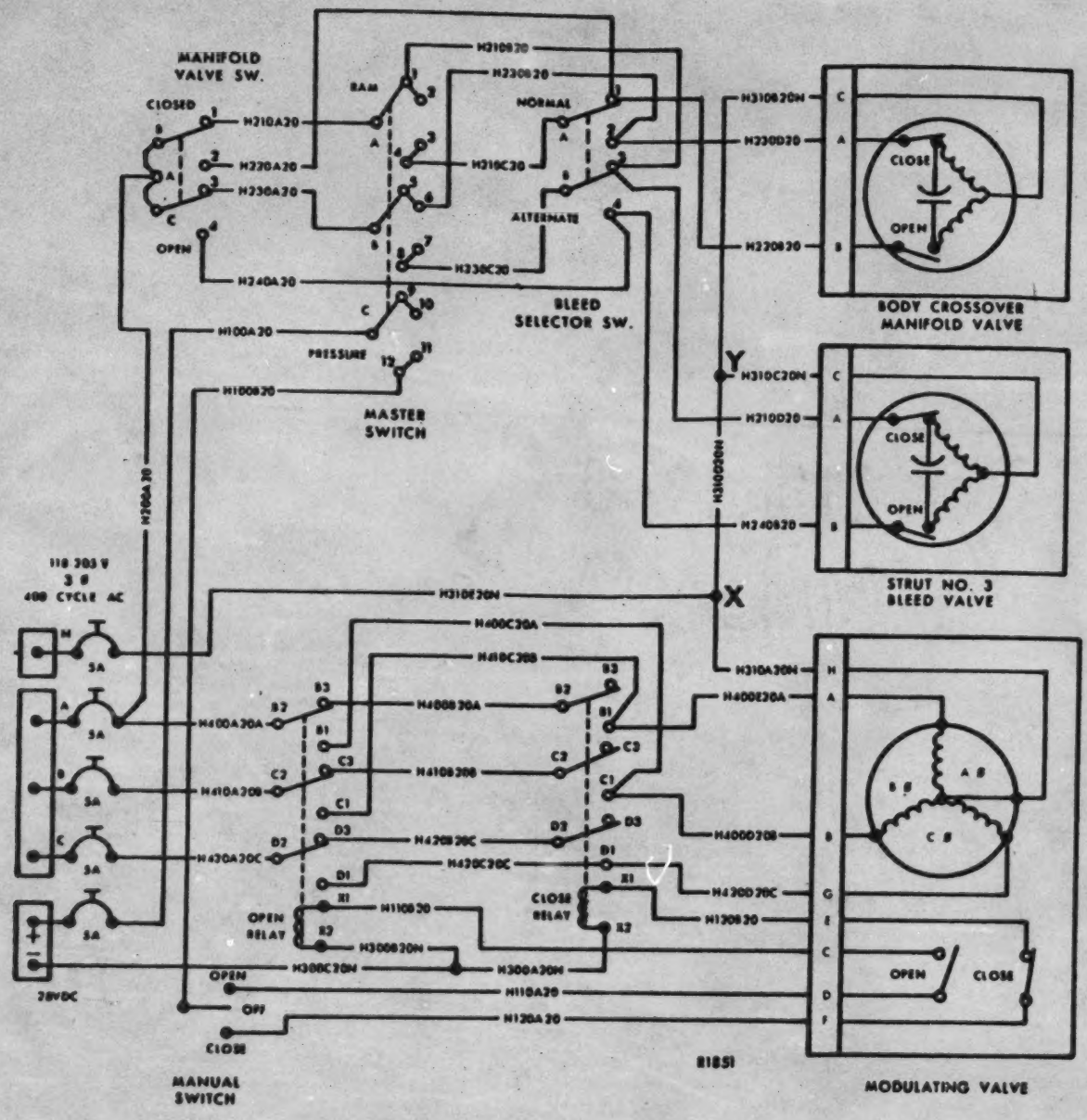
NOTE: The above lines are LIGHT GREEN.

Part 2, Exercise 7 Confirmation.



NOTE: The above bold lines are PURPLE.

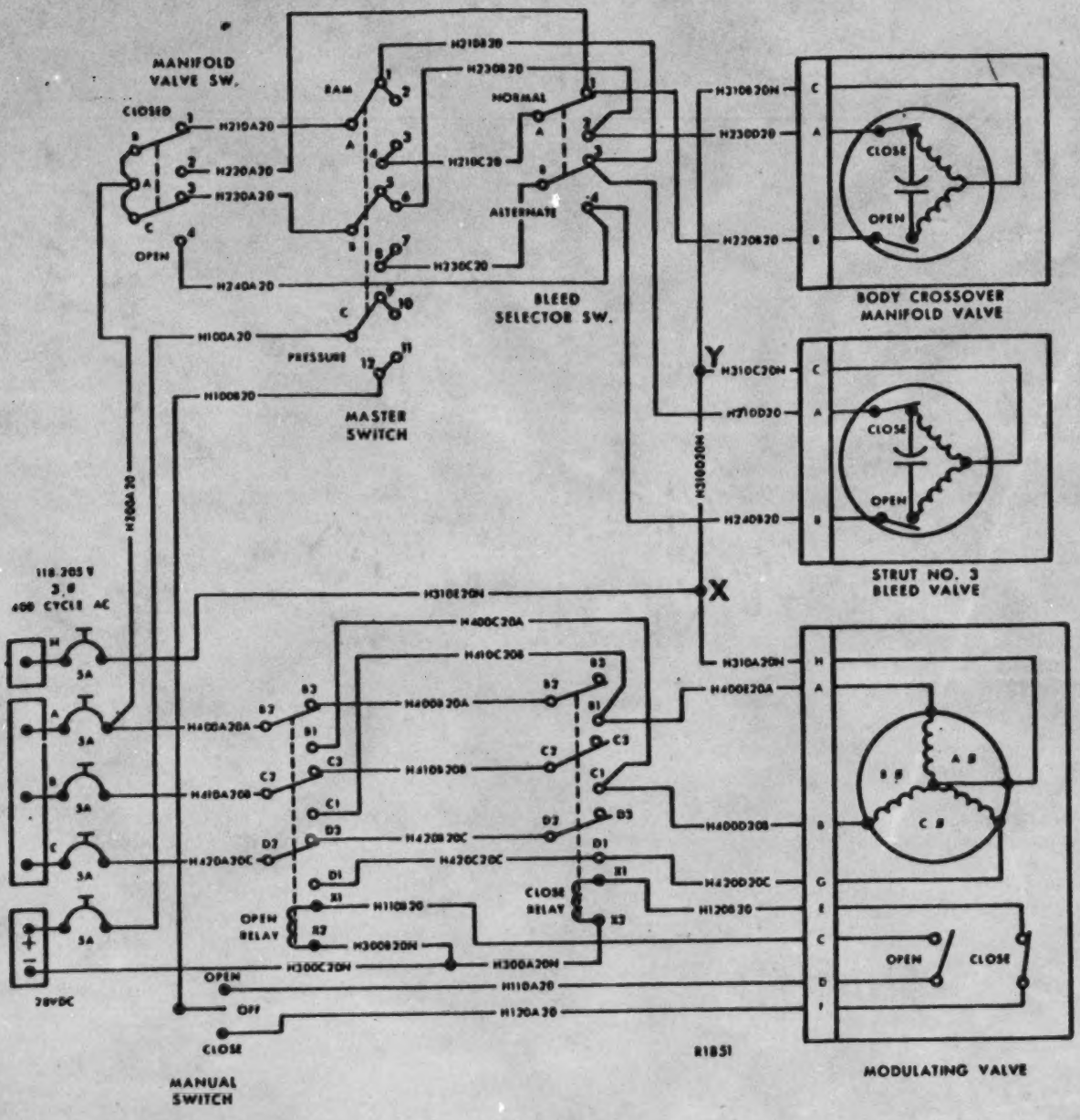
Part 2, Exercise 8 Confirmation.



Exercise 1 (red)

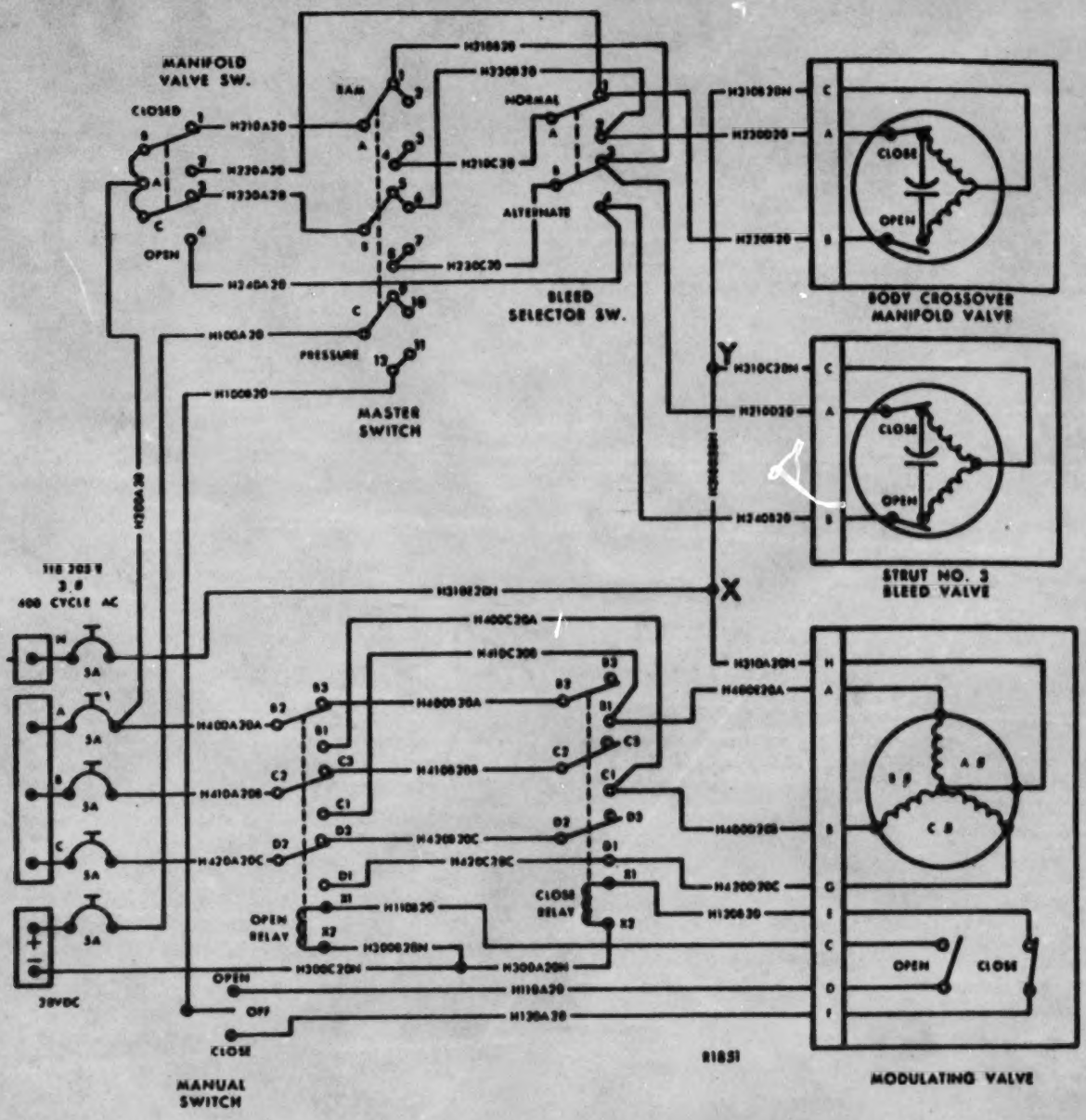
Exercise 2 (dark green)

Part 3, Figure 1.



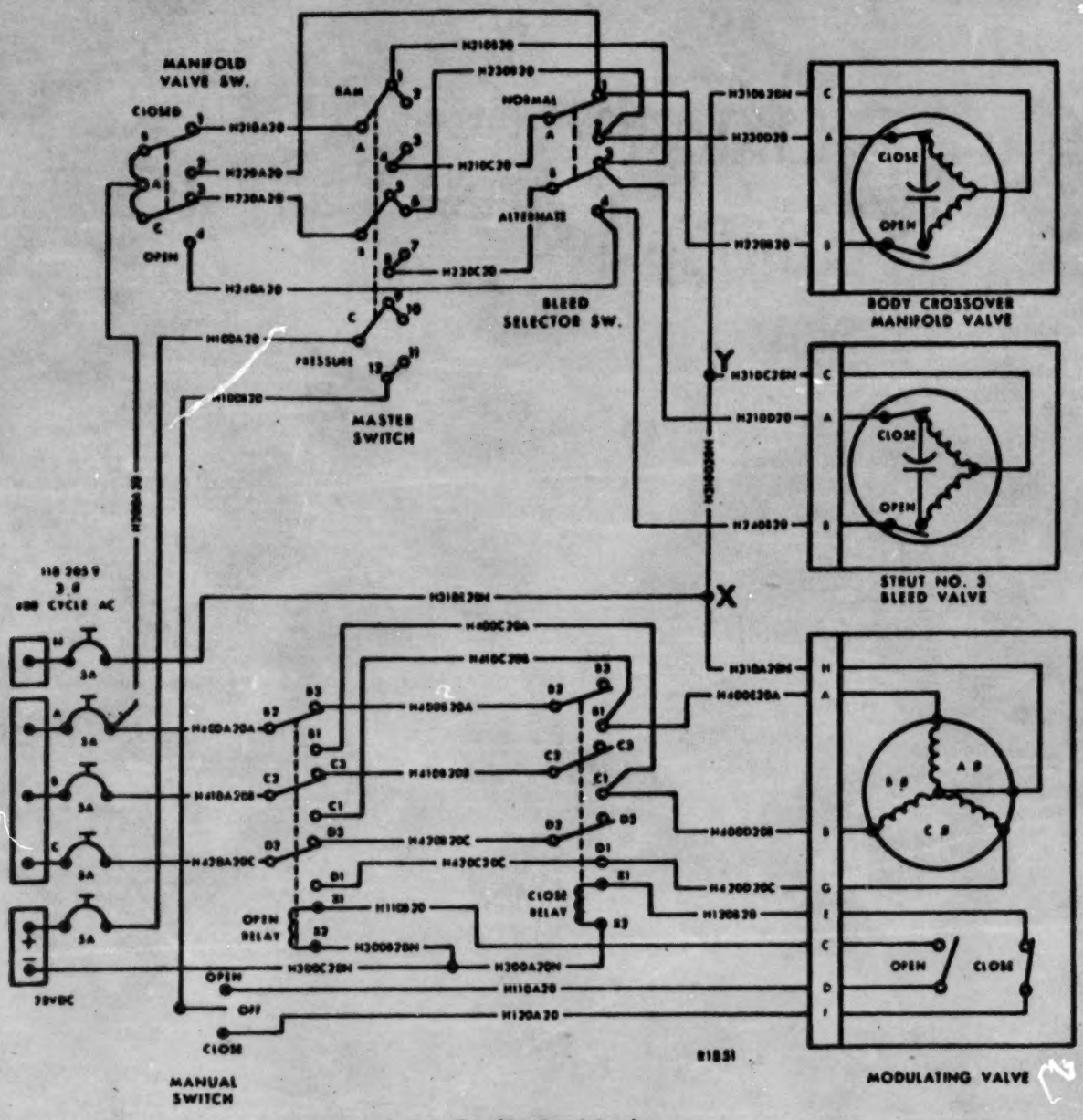
Exercise 3 (dark blue)

Part 3, Figure 2.



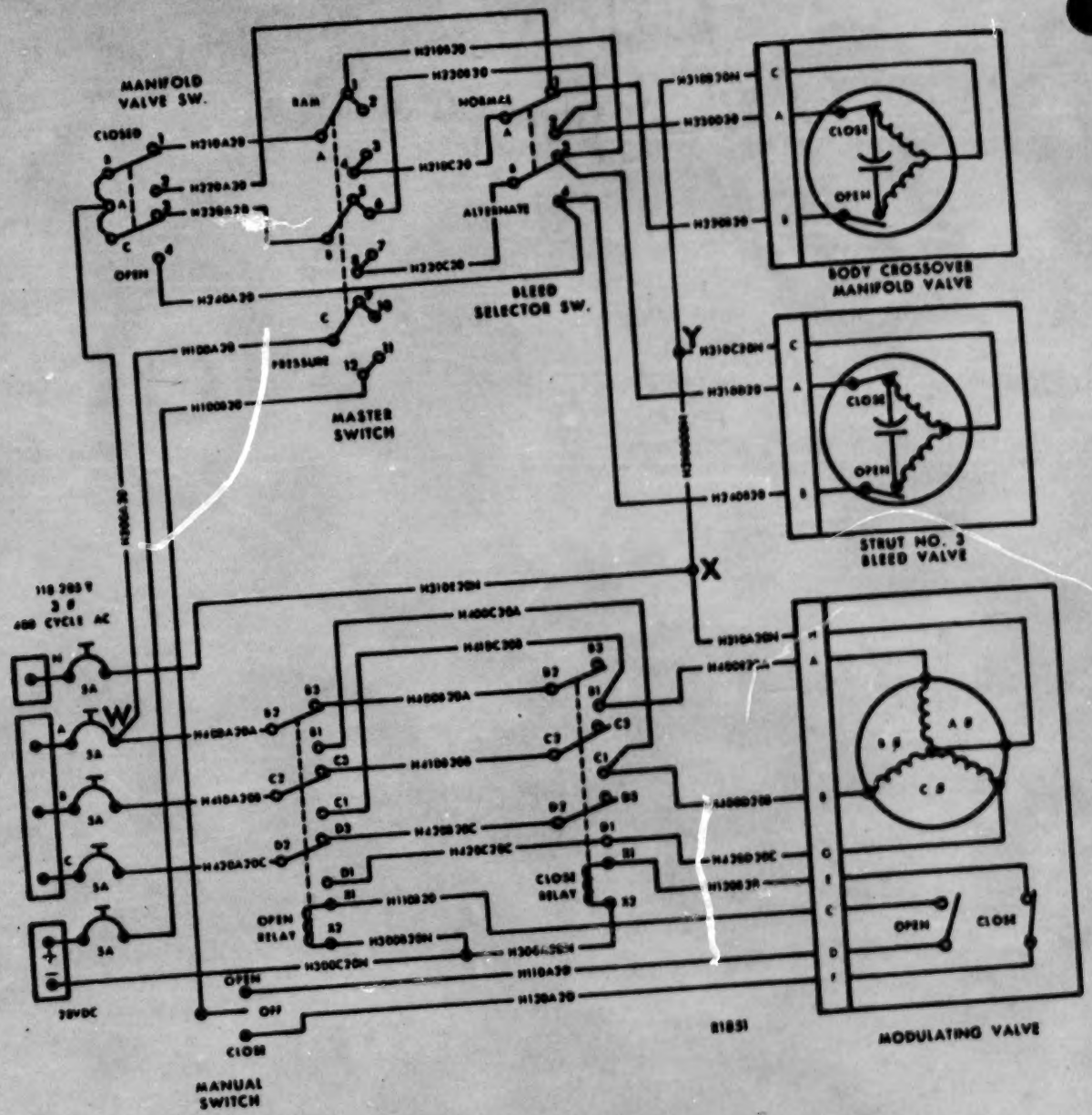
Exercise 4 (orange)

Part 3, Figure 3.



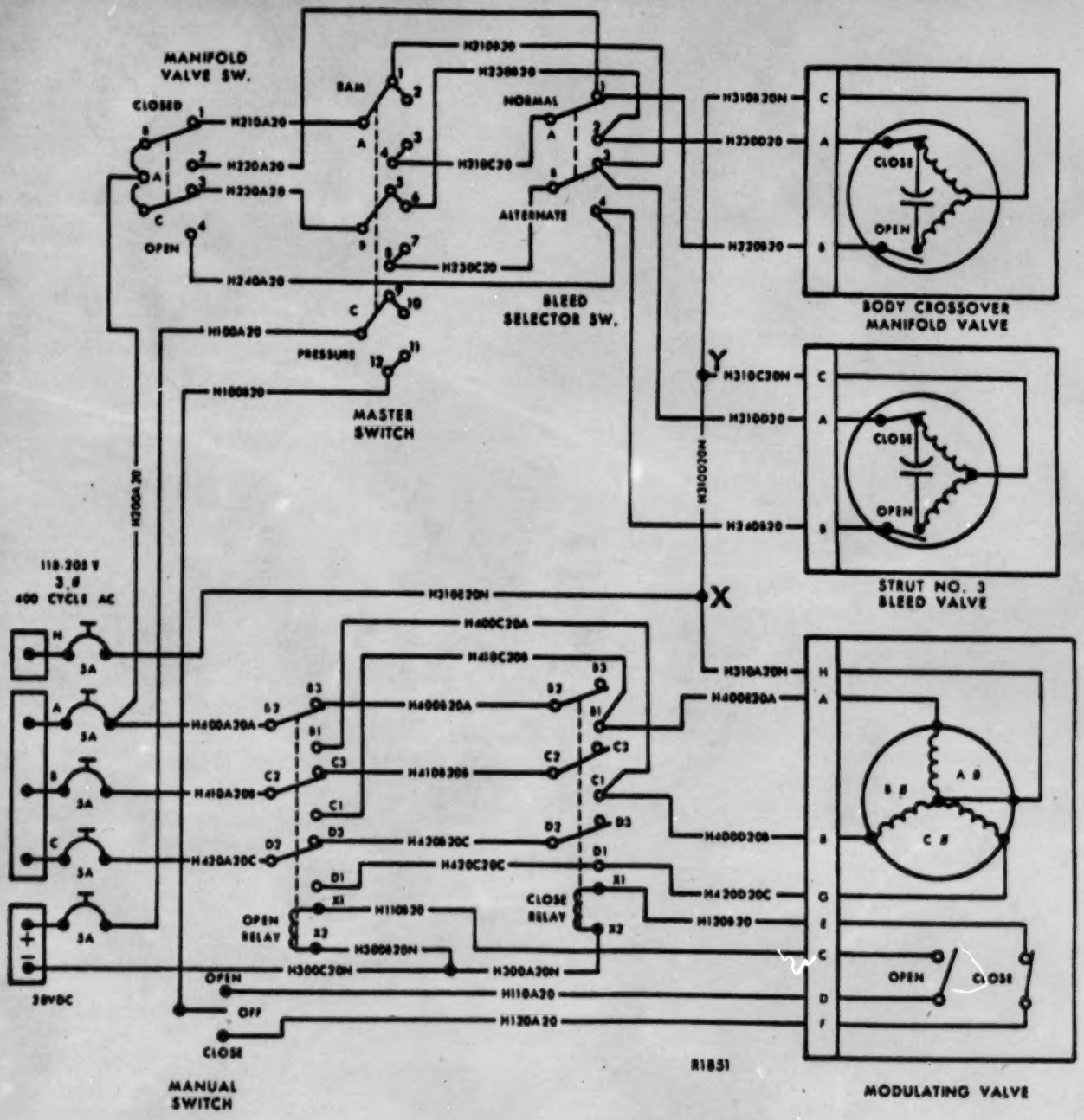
Exercise 5 (light blue)
Exercise 6 (brown and red)
Exercise 7 (light green)

Part 3, Figure 4.



Exercise 8 (purple)

Part 3, Figure 5.


MANIFOLD VALVE SW.
CLOSED
OPEN
RAM
NORMAL
ALTERNATE
BLEED SELECTOR SW.
PRESSURE
MASTER SWITCH
H210A20
H220A20
H230A20
H240A20
H100A20
H100B20
H200A20
H210B20
H220B20
H230B20
H230C20
H310C20
H310B20N
H310C20N
H310D20N
H310A20N
H340B20
H400C20A
H400B20A
H400A20A
H410C20B
H410B20B
H410A20B
H420B20C
H420C20C
H420A20C
H400D20B
H420D20C
H110B20
H300B20N
H300C20N
H300A20N
H110A20
H120A20
H130B20
OPEN RELAY
CLOSE RELAY
118-208 V 3, Ø 400 CYCLE AC
28VDC
OPEN
OFF
CLOSE
MANUAL SWITCH
BODY CROSSOVER MANIFOLD VALVE
STRUT NO. 3 BLEED VALVE
MODULATING VALVE
R1851
X
Y

0801

1081

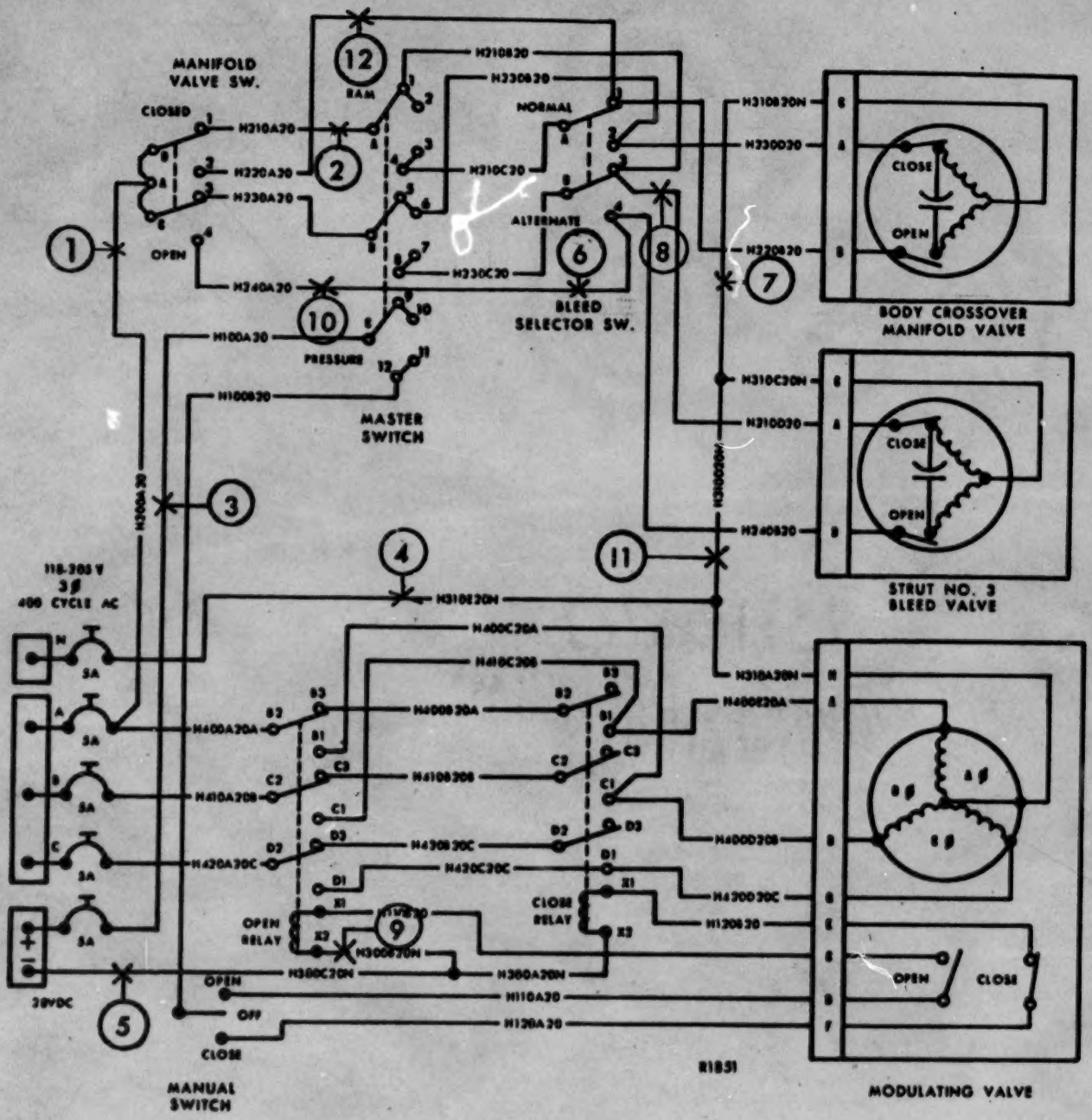


Figure 6.
Foldout 2.

1103

1082

STUDENT'S NAME _____
(last) (first)

DATE PROGRESS CHECK STARTED _____

PROBLEM NUMBERS (REFER TO FOLDOUT #2)	CIRCUIT INDICATIONS				CIRCUIT MALFUNCTIONS											
					BODY CROSSOVER MANIFOLD VALVE				STRUT #3 BLEED VALVE				MODULATING VALVE			
	MANIFOLD VALVE SWITCH	MASTER SWITCH	BLEED SELECTOR SWITCH	MANUAL SWITCH	NO EFFECT	INOPERATIVE	WON'T CLOSE	WON'T OPEN	NO EFFECT	INOPERATIVE	WON'T CLOSE	WON'T OPEN	NO EFFECT	INOPERATIVE	WON'T CLOSE	WON'T OPEN
1	CLOSE	RAM	ALT	OPEN		X				X			X			
2	OPEN	PRESS	NORM	CLOSE												
PRACTICE PROBLEMS 1-2 INSTRUCTOR MUST INITIAL BEFORE PROGRESSION _____																
3	CLOSE	PRESS	NORM	OPEN												
4	CLOSE	PRESS	ALT	CLOSE												
5	CLOSE	PRESS	NORM	CLOSE												
6	OPEN	PRESS	ALT	OPEN												
7	CLOSE	PRESS	NORM	OPEN												
PROGRESS CHECK 3-7 INSTRUCTOR MUST INITIAL BEFORE PROGRESSION _____																
8	CLOSE	RAM	NORM	OPEN												
9	CLOSE	PRESS	NORM	CLOSE												
10	OPEN	RAM	ALT	CLOSE												
11	OPEN	PRESS	ALT	OPEN												
12	CLOSE	RAM	NORM	OPEN												
PROGRESS CHECK 8-12 INSTRUCTOR MUST INITIAL BEFORE PROGRESSION _____																

Figure 7.
Foldout 2. 1104

WORKBOOK
3ABR42331-WB-126A

Technical Training

Aircraft Environmental Systems Mechanic

AC MOTOR AND CONTROL CIRCUITS TROUBLESHOOTING

7 August 1979

CHANUTE TECHNICAL TRAINING CENTER (ATC)
3370 Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE
DO NOT USE ON THE JOB

1084

Environmental Pneudraulics Branch
Chanute AFB, Illinois

3ABR42331-WB-126A

AC MOTOR AND CONTROL CIRCUITS TROUBLESHOOTING

OBJECTIVE

Using an AC motor control circuit, electrical diagram, and multimeter, locate and record a minimum of four out of five trouble causes.

EQUIPMENT

	Basis of Issue
AC Valve Control Systems Trainer P/N 2999	1/student
Multimeter	1/student

Safety

Remove watches, rings, bracelets, etc., before starting any work on the equipment. It is also a good safety practice to work on the equipment with only one hand. This practice reduces the chances of receiving an electrical shock to some vital body organ, when working with electricity.

PROCEDURE

This workbook will be accomplished in the lab. After you get to the lab, ask the lab instructor to assign you to a trainer, to complete this workbook and progress check. You will also need to sign out a multimeter when this workbook instructs you to do so later. Follow the procedures that are given for each exercise.

When you leave your trainer for a scheduled or unscheduled break, insure the following has been done before you go.

1. Place all circuit breakers to the out (deenergized) position.

2. Secure your multimeter during this period.

   a. Insure the controls on the multimeter are properly set for storage.

   b. Leave the test leads attached to the multimeter.

   c. Wrap the meter leads around the instrument.

   d. Place the meter on the locker shelf.

Supersedes 3ABR42331-WB-116A, 22 April 1977.
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3370TCHTG/TTGU-P - 300; TTVSA - 1

3. When you return from the break, take the same meter and go back to work. Insure that power is connected to the trainer and circuit breakers are pushed in as needed.

Before you can effectively troubleshoot the AC motor circuits, you must become thoroughly familiar with the normal operation of the system. An operational checkout MUST be performed, prior to troubleshooting, to determine the condition of the system and to help you locate exactly which portion of the system is defective. Knowing when and how the systems operate normally is the key to successful troubleshooting.

Exercise 1

1. Follow the procedures below to set up the trainer for an operational check and this will also familiarize you with the location of the components.

a. Insure all five (5) circuit breakers (CB) are pulled out.

b. Place the MANIFOLD VALVE SWITCH to the OPEN position.

c. Place the MASTER SWITCH to the PRESSURE position.

d. Place the BLEED SELECTOR SWITCH to the ALTERNATE position.

e. Place the MANUAL SWITCH to the CLOSE position.

f. Place all TROUBLE SWITCH toggles to the OUT position. These are located on the back of the trainer.

g. The small switch that is not labeled near the top of the other trouble switches; be sure it is in the UP position. If it is not you will be unable to troubleshoot the trainer successfully.

h. Insure trainer is plugged in.

i. Push in all five (5) circuit breakers (CB). These will supply AC and DC power to the circuits.

Note: IF the valves on the trainer run after you push in the circuit breakers they are only running to the position for which they are programmed by the switches. This is normal and not a malfunction.

Exercise 2

1. As you perform each of the following steps, place an "X" in the blank that correctly indicates the motor(s) position. You will observe the motor valves operation and also study the electrical diagram on the trainer to answer the questions. The correct answers are at the end of this exercise on page 13.

a. Place the MANIFOLD VALVE SWITCH in the CLOSE position, MASTER SWITCH to the RAM position, BLEED SELECTOR SWITCH to the NORMAL position and the MANUAL SWITCH to the OFF position (centered).

(1) The Body Crossover manifold valve

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(2) The Strut #3 Bleed valve

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(3) The Modulating valve

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

To prove that these valves have functioned normally you could trace the electrical circuit. Start the tracing on the trainer circuit diagram by tracing the switches in the position they actually are on the trainer control panels. Now start tracing the circuit at point "A" on the MANIFOLD VALVE SWITCH, going in both directions. Tracing through the MANIFOLD VALVE SWITCH CLOSE position, through the MASTER SWITCH RAM position, and on through the BLEED SELECTOR SWITCH NORMAL position on to both single phase AC motors. As you can see, because the MASTER SWITCH is in the RAM position, the MANUAL SWITCH will NOT have any control over the MODULATING VALVE.

To aid you in understanding the circuit better be sure you draw in the position of the various switches every time you change their position on the control panels. After this start the tracing at point "A" on the MANIFOLD VALVE SWITCH in both directions tracing through the switches over to the AC valves. If the MASTER SWITCH is in the PRESSURE position be sure you check out the three (3) phase valve control system. Be sure you mark the position of the MANUAL SWITCH with the grease pencil and also the position of the

relay contacts as necessary and also the MODULATING VALVE micro-switches as necessary. If you have any questions at this time about these procedures check with your lab instructor before you progress any further.

b. Place the MANIFOLD VALVE SWITCH in the CLOSE position, MASTER SWITCH to the PRESSURE position, BLEED SELECTOR SWITCH to the NORMAL position and the MANUAL SWITCH to the OPEN position.

(1) The BODY CROSSOVER MANIFOLD VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(2) The STRUT #3 BLEED VALVE.

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(3) The MODULATING VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

Note: When the master switch is placed in the pressure position, you should also trace out the DC circuits. This starts at the positive (+) DC bus bar and on through the master switch, manual switch, and on through the motor micro-switches on through the correct relay coil to the DC ground.

Check your answers on page 13. If they are correct move on to the next operation. If any are incorrect, STOP and see your lab instructor at this time.

1095

c. Place the MANIFOLD VALVE SWITCH in the CLOSE position, MASTER SWITCH to the RAM position, BLEED SELECTOR SWITCH to the ALTERNATE position and the MANUAL SWITCH to the OFF position (center).

(1) The BODY CROSSOVER MANIFOLD VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(2) The STRUT #3 BLEED VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(3) The MODULATING VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

Check your answers on page 13. If they are correct move on to the next operation. If any are incorrect, STOP and see your lab instructor at this time.

1110

d. Place the MANIFOLD VALVE SWITCH in the CLOSE position, MASTER SWITCH to the PRESSURE position, BLEED SELECTOR SWITCH to the ALTERNATE position and the MANUAL SWITCH to the CLOSE position.

(1) The BODY CROSSOVER MANIFOLD VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(2) The STRUT #3 BLEED VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(3) The MODULATING VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

Check your answers on page 13.

1090

e. Place the MANIFOLD VALVE SWITCH in the OPEN position, MASTER SWITCH to the RAM position, BLEED SELECTOR SWITCH to the NORMAL position and the MANUAL SWITCH to the OFF position.

(1) The BODY CROSSOVER MANIFOLD VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(2) The STRUT #3 BLEED VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(3) The MODULATING VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

Check your answers on page 13.

1112

f. Place the MANIFOLD VALVE SWITCH in the OPEN position, MASTER SWITCH to the PRESSURE position, BLEED SELECTOR SWITCH to the NORMAL position and the MANUAL SWITCH to the OPEN position.

(1) The BODY CROSSOVER MANIFOLD VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(2) The STRUT #3 BLEED VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(3) The MODULATING VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

Check your answers on page 13.

1092

g. Place the MANIFOLD VALVE SWITCH in the OPEN position, MASTER SWITCH to the RAM position, BLEED SELECTOR SWITCH to the ALTERNATE position and the MANUAL SWITCH to the OFF position.

(1) The BODY CROSSOVER MANIFOLD VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(2) The STRUT #3 BLEED VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(3) The MODULATING VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

Check your answers on page 13.

1114

h. Place the MANIFOLD VALVE SWITCH in the OPEN position, MASTER SWITCH to the PRESSURE position, BLEED SELECTOR SWITCH to the ALTERNATE position and the MANUAL SWITCH to the CLOSE position.

(1) The BODY CROSSOVER MANIFOLD VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(2) The STRUT #3 BLEED VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

(3) The MODULATING VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

Check your answers on page 13.

1094

i. Place the MANIFOLD VALVE SWITCH in either position, MASTER SWITCH to the PRESSURE position, BLEED SELECTOR SWITCH to either position and the MANUAL SWITCH to the OPEN position.

(1) The MODULATING VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

Note: Be sure you place the switches in the correct position with the grease pencil on the trainer wiring diagram. This will aid you in understanding and later, troubleshooting the circuits.

j. Place the MANIFOLD VALVE SWITCH in either position, MASTER SWITCH to the PRESSURE position, BLEED SELECTOR SWITCH to either position and the MANUAL SWITCH to the CLOSE position.

(1) The MODULATING VALVE

_____ a. OPENED.

_____ b. CLOSED.

_____ c. should not operate.

Note: Operation (i and j). The MASTER SWITCH being in the PRESSURE position allows the MANUAL SWITCH to control the three (3) phase modulating VALVE. This should result regardless of the position of the MANIFOLD VALVE SWITCH and the BLEED SELECTOR SWITCH.

Check your answers on page 13.

1116

This completes the operational check procedures; now compare your answers to those given if you have not already done so. This way you will know that the trainer is operating normally. If you have any questions STOP and see your lab instructor before progressing.

Correct response to Exercise 2:

a. (1) b
(2) b
(3) c

b. (1) a
(2) c
(3) a

c. (1) b
(2) c
(3) c

d. (1) c
(2) a
(3) b

e. (1) a
(2) c
(3) c

f. (1) c
(2) c
(3) a

g. (1) c
(2) c
(3) c

h. (1) c
(2) c
(3) b

i. (1) a

j. (1) b

1096

Exercise 3

If you are thoroughly familiar with the normal operation of the system you will now start with troubleshooting. If you are in doubt about the normal operation of the system, see your lab instructor. Also be sure you understand how to use the grease pencil to mark the switches and follow the circuit. If you don't understand ask the lab instructor NOW.

1. Follow the procedures below to program a CAUSE for a malfunction in the electrical circuit.

a. Insure power is connected to the trainer. See your lab instructor if needed.

b. Place the MANIFOLD VALVE SWITCH to the CLOSED position.

c. Place the MASTER SWITCH to the RAM position.

d. Place the BLEED SELECTOR SWITCH to the NORMAL position.

e. Place the MANUAL SWITCH to the OFF position.

f. Insure the circuit breakers (CB) are pushed in.

g. Sign out a multimeter and insure it is propoerly set up and leads are connected correctly to the meter.

Note: As you can see on the wiring diagram, the bus bar has AC and DC power so be careful the multimeter is set up correctly for whichever value you intend to measure. DO NOT use the ohms portion of the multimeter on this trainer until you check with the lab instructor.

h. Insure that all the troubles switches on the back of the trainer are in the OUT position.

i. Now place trouble switch #3 on the back of the trainer to the IN position.

Note: If you see motor operation disregard it at this time.

Now you are ready for the operational check of the system. Remember you are now looking for a visual malfunction of the valve(s) during the operational check.

Note: You are going to use trouble #3 on the back of the trainer for the first practice malfunction problem. The trouble switch on the back of the trainer, when placed to the "IN" position, will place a CAUSE in the electrical control circuit giving a visual malfunction of a valve. Because the location, in the circuit, of the CAUSE for the malfuction is unknown to you, you will need to perform a complete operational check and then troubleshoot the malfunctioning circuit with a multimeter. Once you have moved a trouble switch to the IN position you will leave it there until this workbook and/or instructor instructs you otherwise.

To perform the operational check you will place the switches in the position you desire and mark the switches in that position on the electrical diagram on the trainer. Now you start at point "A" of the MANIFOLD VALVE SWITCH and trace in both directions to the valves to determine their required operations. If they do not perform as required, you have then found the observable malfunction to record on the chart on page 17. If you have any questions at this time see your instructor. You may use the steps in Exercise 2 to assist you in the operational check or you may position the control switches on the panel as you wish. If you do this be sure you still use a grease pencil to mark the switch position and circuit wiring to identify what functioned or failed to function.

What have you found to be malfunctioning? RIGHT! The body crossover manifold valve is working backwards or in reverse. If you have used Exercise 2 you will find the body crossover manifold valve malfunctioned when you compare operation (step) (a and e OR d and h).

Now look at your list of possible malfunctions on page 17. You see that it would be letter "D". Write the letter "D" on your practice problems chart under malfunction for trouble switch #3. Trouble switch #3 has already been completed for you.

Now you are ready to troubleshoot the control circuit and to find the CAUSE for the observable malfunction for trouble switch #3. You will use the voltage measuring method of troubleshooting. This procedure starts at the connector plug of the malfunctioning unit (load) or motor winding. You will take the first voltage measurement on the positive side of the unit (load) which failed to function correctly. Having the correct amount of power in the positive circuit up to the malfunctioning unit (load) indicates that the positive circuit is OK. This first voltage check taken at the plug will tell you to continue troubleshooting the positive control circuit or troubleshooting the ground circuit. If the voltage reading is below the required value you would continue troubleshooting in the positive control circuit. If the required value is measured you would then check out the ground circuit for the malfunction load.

Note: Insure that you place the meter controls to the proper setting for voltage checks.

Follow the following instructions to solve for the CAUSE of malfunction.

a. Connect the black lead from the meter to the common ground point on the trainer, there is one for AC and one for DC. You must be careful in selecting the correct ground.

b. Use the RED lead and measure the applied voltage on the positive side of the malfunctioning unit (load).

Note: Remember you must place the switches in the position the malfunction is happening. You will need to use either two (2) of the four (4) steps, (a and e OR d and h) from exercise 2.

(1) Measuring the voltage at points A and B of the BODY CROSSOVER VALVE, you will find that they are reversed.

(2) Measuring the voltage at points 1 and 2 of the BLEED SELECTOR SWITCH, you will find that the readings are normal.

c. Now that you have found the CAUSE, the two wires reversed or crossed, H230D20 and H220B20, you will make the correct entries on the practice problems chart, page 17.

(1) Identify the malfunction by writing in the letter(s) which identify the malfunction. (These have already been done for you.)

(2) Complete the CAUSE columns by writing in the type of trouble and unit or wire number. (These have already been done for you.)

(3) See your lab instructor if you have any questions at this time.

h. Referring to the practice chart on page 17, you will find all the required entries already made for trouble switch #3. Study the entries already made to acquire knowledge on how to make the entries for the remaining trouble switches.

Exercise 4

You have completed troubleshooting trouble #3. You should be able to troubleshoot a malfunction on your own at this time. You may ask for assistance from the lab instructor if necessary.

1. Following the procedures below practice programming a cause for a malfunction in the trainer.

a. Insure the switches on the front of the trainer are in the position of your choosing. You may want to use Exercise 2.

b. Insure circuit breakers are in.

c. Insure multimeter is properly set up and leads connected to the meter.

d. Insure that all the trouble switches on the back of the trainer are in the OUT position.

e. See the instructor to have a trouble switch # entered in the practice problem and progress check charts, pages 17 and 20.

f. Set your switches first as shown in Exercise 1, set up procedures.

g. Now place the trouble switch on the back of the trainer matching the number entered on the practice problem chart, to the IN position.

2. Perform an operational check.

3. Complete the malfunction column on the practice problem chart. You may need more than one letter in this column.

4. Troubleshoot the circuit(s) for the cause, using the meter.

5. Complete the cause columns below.

6. Check the wire number against your entry in the malfunction column for recheck of your work. Note: Remember how you did your wiring diagram workbook in the classroom and use that knowledge to cross check this work.

7. Have your instructor check and initial your work before progression. If your work is incorrect follow the instructions given by the instructor.

Note: BEFORE you place any trouble switch to the IN position, be sure the four (4) control switches on the front of the trainer are set as indicated below.

MANIFOLD VALVE SWITCH . . . . . OPEN

MASTER SWITCH . . . . . PRESSURE

BLEED SELECTOR SWITCH . . . . . ALTERNATE

MANUAL SWITCH . . . . . CLOSE

PRACTICE PROBLEMS			
TROUBLE		CAUSE	
SWITCH #	MALFUNCTION	TYPE OF TROUBLE	WIRE NUMBER(S)
3	D	Cross Wires	H230D20 & H220B20

LIST OF POSSIBLE MALFUNCTIONS

(There can be more than one malfunction for each problem)

A. Body crossover manifold valve will not open.
B. Body crossover manifold valve will not close.
C. Body crossover manifold valve will not operate.
D. Body crossover manifold valve runs backwards (reverse).
E. Strut #3 bleed valve will not open.
F. Strut #3 bleed valve will not close.
G. Strut #3 bleed valve will not operate.
H. Strut #3 bleed valve runs backwards (reverse).
I. Modulating valve will not open.
J. Modulating valve will not close.
K. Modulating valve will not operate.
L. Modulating valve runs backwards (reverse).

1100

Before you have your instructor check your work, recheck your own work. You should recheck your work much like you solved the problems in the AC Motor Control circuit wiring diagrams workbook. This may be done by taking the wire number you have written above and using the wiring diagram located on the trainer. Doing this you can determine if the malfunction(s) you have written in the chart above are 100% correct.

Note: Be very careful in rechecking by selection of the circuit malfunction. They must describe exactly what is malfunctioning, nothing more or less. Also always note the position of the control switches.

Instructor's Initial: _____ Practice Problems Grade: _____

If your lab instructor signs off your practice work you will be assigned your progress check material by the lab instructor.

1122

PROGRESS CHECK INSTRUCTIONS

This progress check will require you to correctly solve a minimum of four (4) out of the five (5) problems given. This should be accomplished much in the same manner as the practice problems. The instructor will check and initial your work after the five (5) problems are graded and passed. If you have missed more than one (1) problem you will follow your lab instructor instructions.

You will not communicate (talk, etc) with other students during the progress check without your lab instructor's permission.

You will not use fellow students' work to solve the problems in this progress check.

You should satisfactorily complete this progress check before further progression to other lab troubleshooting progress checks.

Note: If any part of the answers (cause or malfunction) to the trouble switch # is wrong, the instructor will mark the whole trouble switch entry incorrect. This means YOU will have to find what part or parts of the cause or malfunction is incorrect for that trouble switch, when marked incorrect.

REMINDER: BEFORE you place any trouble switch to the IN position, be sure the four (4) control switches on the front of the trainer are set as indicated below.

MANIFOLD VALVE SWITCH . . . . . OPEN

MASTER SWITCH . . . . . PRESSURE

BLEED SELECTOR SWITCH . . . . . ALTERNATE

MANUAL SWITCH . . . . . CLOSE

1102

Student complete the following (print).

STUDENT's NAME: _____
Last First

DATE PROGRESS CHECK STARTED: _____

PROGRESS CHECK			
Trouble Switch #	MALFUNCTION	CAUSE	
		TYPE OF TROUBLE	WIRE NUMBER(S)

LIST OF POSSIBLE MALFUNCTIONS

(There can be more than one malfunction for each problem)

A. Body crossover manifold valve will not open.
B. Body crossover manifold valve will not close.
C. Body crossover manifold valve will not operate.
D. Body crossover manifold valve runs backwards (reverse).
E. Strut #3 bleed valve will not open.
F. Strut #3 bleed valve will not close.
G. Strut #3 bleed valve will not operate.
H. Strut #3 bleed valve runs backwards (reverse).
I. Modulating valve will not open.
J. Modulating valve will not close.
K. Modulating valve will not operate.
L. Modulating valve runs backwards (reverse).

Before you have your instructor check your work, recheck your own work like you did in the practice problems.

Instructor's Initial: _____ Grade: _____ on complete progress check.

Whether you fail this progress check or not, you will follow the instructions of the lab and/or classroom instructor(s) at this time.

1124

If you have satisfactorily completed the progress check, store your multimeter and trainer in the following way.

1. Pull out all the circuit breakers (5) each.

2. Place the Manifold valve switch to the CLOSED position.

3. Place the Master switch to the RAM position.

4. Place the Bleed Selector switch to the NORMAL position.

5. Place the Manual switch to the CLOSE position (centered).

6. Place all Trouble switches to the OUT position.

7. The small switch that is not labeled near the top of the other trouble switches; be sure it is in the UP position.

8. Insure all your training literature, pencils, etc., are taken with you when you leave the lab.

9. Insure your trainer and the area around it is clean before you leave the lab.

10. Check with the lab instructor before you leave the lab.

NOTE: DID YOU LEAVE YOUR MULTIMETER SET ON OHMS? IF YOU HAVE, GO BACK AND CHANGE IT.

PROGRAMMED TEXT
3ABR42331 - PT 127

Technical Training

Aircraft Environmental Systems Mechanic

PRINCIPLES OF SOLID STATE DEVICES

25 March 1976

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
3370th Technical Training Group
Chanute Air Force Base, Illinois

DESIGNED FOR ATC COURSE USE.

DO NOT USE ON THE JOB.

1105

FOREWORD

This programmed text is designed for use in the 3ABR42231 Course. The average time required to complete this text was 1 hour and 28 minutes.

OBJECTIVES

After completing this programmed text, you will be able to:

1. State the difference between insulators, conductors, and semiconductors.

2. State the purpose and identify the symbol of a PN junction diode.

3. Select statements that define the difference between forward and reverse bias.

4. State the purpose and identify the symbol of a Zener diode.

5. State the purpose and identify the symbol of a transistor.

6. Select statements that describe the requirements for a transistor to conduct.

STANDARD OF PERFORMANCE

The student will demonstrate his knowledge of the objectives by correctly answering 12 out of 15 questions.

INSTRUCTIONS

This program text presents information in small steps called "frames." After each frame you are asked to complete a statement or match some statements. Read the material presented and make your response as directed. After you have made your response, compare your answer with the correct answer given on the page following each frame. If your answer is incorrect, restudy the frame to get the information correct. Write the correct answer next to your original response and then proceed to the next frame. If necessary, you may go back to check information previously given, but do not skip ahead.

INTRODUCTION

Solid state devices are miniature electronic components used to control or amplify current in an electronic circuit. The solid state devices that will be described in this text are PN junction diodes, Zener diodes, and transistors.

Supersedes 3ABR42231-PT-113, 16 October 1972, which may be used until existing stocks are exhausted.
OPR: TAS
DISTRIBUTION: X
TAS - 150; TTVOC - 1

1106

The PN junction diode is used in almost every temperature control circuit. This text will describe how the PN junction diode is constructed, how it reacts to changes in current flow, and its purpose in today's temperature control circuits.

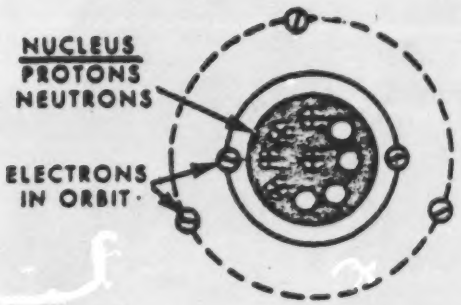
The Zener diode is similar to the PN junction diode, except that its function in a circuit is different. This text will explain how the Zener diode is used as a control device and how it is used to regulate voltage.

The transistor also operates on the same principles as the PN junction diode. In this text you will be shown how the transistor operates and how it is used in a temperature control circuit.

Understanding the operating principles of these three devices is very important when studying the operation of temperature control systems.

1128

To understand the principles of solid state devices, we must have a short review of electron theory. An atom is made up of PROTONS, NEUTRONS, and ELECTRONS. The protons and neutrons make up the center part of the atom which is called the NUCLEUS. The electrons are held in orbit around the nucleus. This is shown in the sketch below. Electrons have a negative charge and protons have a positive charge. The neutrons are neutral, which means they have no electrical charge.



Fill in the blanks to complete the following statements.

1. Atoms are composed of _____, _____, and _____.
2. Electrons have a _____ charge.
3. Protons have a _____ charge.
4. Electrons orbit around the _____ of an atom.
5. Protons and neutrons make up the _____ of an atom.

1108

Answers to frame 1: 1. protons neutrons electrons 2. negative

3. positive 4. nucleus 5. nucleus

FRAME 2

In some materials the atoms have many electrons orbiting around their nuclei. Some of these electrons are in orbits distant from the nucleus. This will make it easier to get the electrons to flow from one atom to another. These materials are said to have "free electrons." The atoms of other materials tend to resist the efforts toward electron flow. These materials are said to have almost no free electrons.

A material that has many free electrons is a conductor of electricity. Some examples of conductors are copper, silver, and gold. When a voltage is applied to a conductor, the free electrons can move with little or no resistance. This is called current flow. The materials that contain almost no free electrons are called insulators. Some examples of insulators are rubber, glass, and paper. These materials will oppose current flow.

Fill in the blanks to complete the following statements.

1. An insulator contains almost no _____ electrons.

2. Conductors contain many _____ electrons.

3. Normally current will not flow through an _____.

4. Copper, gold, and silver are some examples of _____.

5. Current flow is the movement of _____ through a conductor.

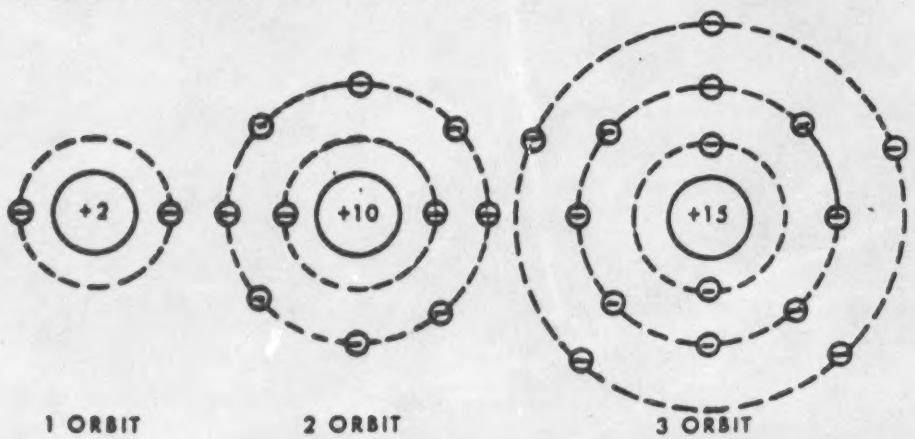
Answers to frame 2: 1. free 2. free 3. insulator 4. conductors 1109
5. electrons

FRAME 3

Let's go on with our review of atomic structure and learn a new term. In each atom there are a specific number of electrons that orbit the nucleus. These electrons will be divided into a definite number of orbital paths. The actual number of electrons and the number of orbital paths will change with the types of material used. This fact in shown in the sketch in this frame. The number of orbits will depend on the number of electrons. In a balanced atom, the number of electrons will be equal to the number of protons. Note the number of electrons, protons and orbits in the sketch shown.

The electrons in the outermost orbit are called VALENCE electrons. As we explain the principles of solid state devices we will be concerned with these valence electrons. Remember this term and that these are the electrons in the outermost orbit.

A stable atom will have eight valence electrons. The maximum number of valence electrons in any atom is eight. Some atoms may have less than eight valence electrons but never more.



Fill in the blanks to complete the following statements.

1. The electrons in the outermost orbit of an atom are called _____ electrons.

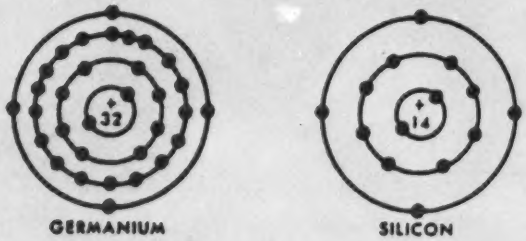
2. The maximum number of electrons in the outermost orbit of an atom is _____.

1110

Answers to frame 3: 1. valence 2. eight

FRAME 4

The two basic materials used in the construction of solid state devices are germanium and silicon. The electron structure of these atoms is shown below. Note that the germanium contains 32 electrons and silicon only 14 electrons. Now note the number of valence electrons in each of these atoms. They both have four. Our discussion on solid state devices will be based on this point. Because each of these materials have four valence electrons, their application to solid state devices is similar. For this reason we will use germanium in this text.



GERMANIUM SILICON

Fill in the blanks to complete the following statements.

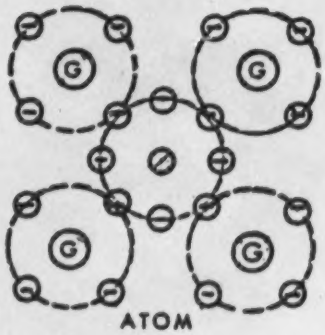
1. The two basic materials used in the construction of solid state devices are _____ and _____.

2. Germanium and silicon are similar because they both have four _____ _____.

Answers to frame 4: 1. germanium silicon 2. valence electrons

FRAME 5

In frame 3 it was stated that an atom is stable when it has eight valence electrons. A stable atom has no free electrons. When a group of germanium atoms are joined together to form a mass, the material will act as though the atoms are stable. This is because the valence electrons of one atom will join with the valence electrons of the atoms close to it. This makes each atom act as if it has eight valence electrons. This is shown in the sketch below.



ATOM

Fill in the blanks to complete the following statements.

1. A stable germanium atom is one with _____ electrons in the valence orbit.

2. When a group of germanium atoms are joined, the material will react as if the atoms were _____.

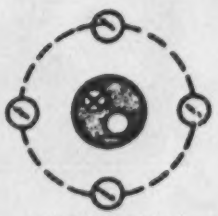
1112

Answers to frame 5: 1. eight 2. stable

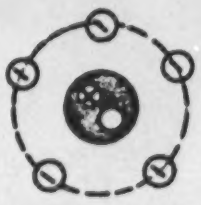
FRAME 6

Solid state devices are made from materials known as semiconductors. A semiconductor is a man made substance. It is made by joining a material that has a different number of valence electrons with the germanium. The atoms that are joined with the germanium are called impurity atoms. The impurity atoms have either three or five valence electrons. In either case, when the impurity atoms are added to the germanium, the stable state of the germanium is changed.

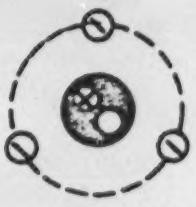
An impurity that has three valence electrons is called an ACCEPTOR atom. Some examples are aluminum, indium, and gallium. An impurity that has five valence electrons is called a DONOR ATOM. Some examples are arsenic, phosphorous, and antimony. In the sketch below, compare the valence electrons of the donor and acceptor to the germanium atom.



GERMANIUM



DONOR



ACCEPTOR

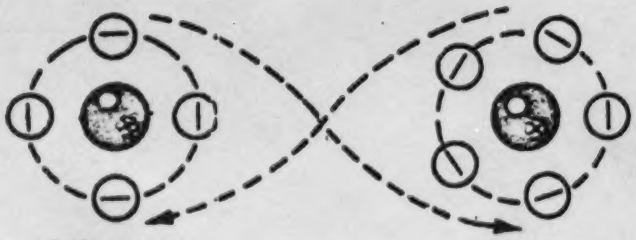
Fill in the blanks to complete the following statements.

1. Germanium can be altered by adding _____ atoms.
2. The number of valence electrons in a donor atom is _____.
3. The number of valence electrons in an acceptor atom is _____.

Answers to frame 6: 1. impurity 2. five 3. three

FRAME 7

Now let's see what change the donor has had on the germanium. When the donor atom is joined with a germanium atom, four of the electrons of the donor join the germanium atom. But since the donor atom has five valence electrons, one is left free to move in any direction. The material now has an excess electron which will give it a negative charge. Because of this, material containing a donor impurity is called N-type material. The sketch below shows the effect of joining a donor atom with a germanium atom.



N-TYPE

4 + 5=9 ELECTRONS AVAILABLE
4→BEING JOINED BY←4= 8 ELECTRONS NEEDED

1 FREE ELECTRON

Fill in the blanks to complete the following statements.

1. N-type material consists of germanium combined with a _____ atom.
2. N-type material contains a _____ charge.
3. A donor atom contains _____ valence electrons.

1114

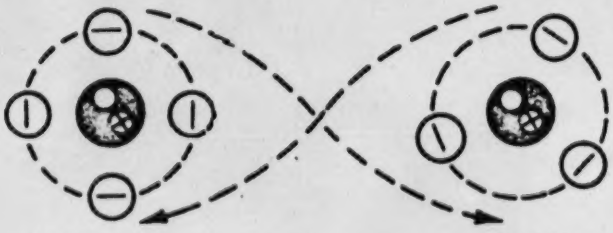
Answers to frame 7: 1. donor 2. negative 3. five

FRAME 8

Now, let's see how the germanium will change when an acceptor impurity is added to it. When the acceptor atom is joined with a germanium atom, the valence orbit will have seven electrons. Remember, to be stable, an atom needs eight valence electrons. When the acceptor atom is joined with the germanium, it leaves a space where one more electron can fit. This space is called a HOLE, and it can take on an electron.

The last frame stated that an atom that had an excess of electrons had a negative charge. In view of this, if an atom lacks an electron, it must have a positive charge. When an acceptor is joined to a germanium atom it becomes a positively charged atom. This positively charged atom (a material that has holes) is called P-type material.

The sketch below shows the effect of combining an acceptor atom with a germanium atom.



P-TYPE

GERMANIUM ACCEPTOR

4 + 4=8 ELECTRONS NEEDED
4 + 3=7 ELECTRONS AVAILABLE

1 ELECTRON SHORT OF BEING BALANCED

Fill in the blanks to complete the following statements.

1. An acceptor atom has _____ valence electrons.

2. P-type material has a _____ charge.

3. When an acceptor atom is joined with a germanium atom, it leaves a space called a _____.

Answers to frame 8: 1. three 2. positive 3. hole

FRAME 9

Match the terms given in column B with the statements listed in column A. Place the letter that identifies the correct term in the blank provided. Column B has more responses than needed. Select only one for each question.

A	B
1. The number of valence electrons in a stable germanium atom is _____.	A. Nucleus
2. The material used in solid state devices is called a _____.	B. Atom
3. Electrons in the outermost orbit are called _____.	C. Four
4. A material having many free electrons is a _____.	D. Semiconductor
5. An impurity atom having three valence electrons is an _____ atom.	E. Electron
6. An impurity atom having five valence electrons is a _____ atom.	F. Eight
7. The particle that orbits the nucleus of an atom is the _____.	G. Valence electrons
8. When germanium is combined with an acceptor atom it is called _____ material.	H. Conductor
	I. Insulator
	J. Donor
	K. Acceptor
	L. N-type
	M. P-type

1116

Answers to frame 9: 1. F 2. D 3. G 4. H 5. K 6. J
7. E 8. M

FRAME 10

Solid state devices are made of N-type and P-type materials joined together. When these materials are joined, as shown in figure A, a device is formed that is known as a PN JUNCTION. Because these two types of materials are joined, a "potential barrier" is formed as shown in figure B. This barrier will oppose electron flow until the right voltage potential is applied to the junction. This voltage is known as BIAS VOLTAGE. Bias voltage is usually DC, and is used to fix or set the current flow in a circuit. The two types of bias used are FORWARD and REVERSE.

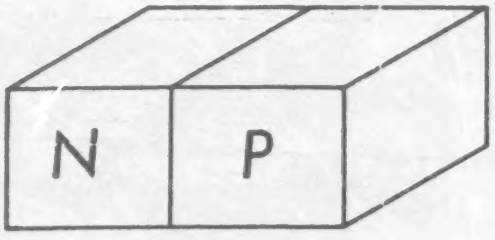


Figure A

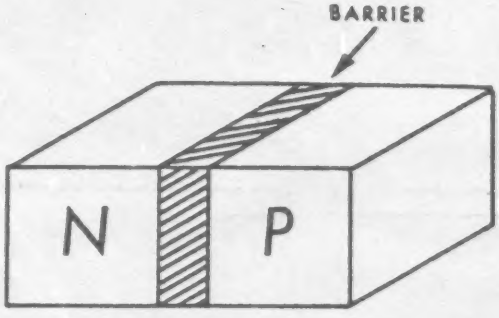


Figure B

Fill in the blanks to complete the following statements.

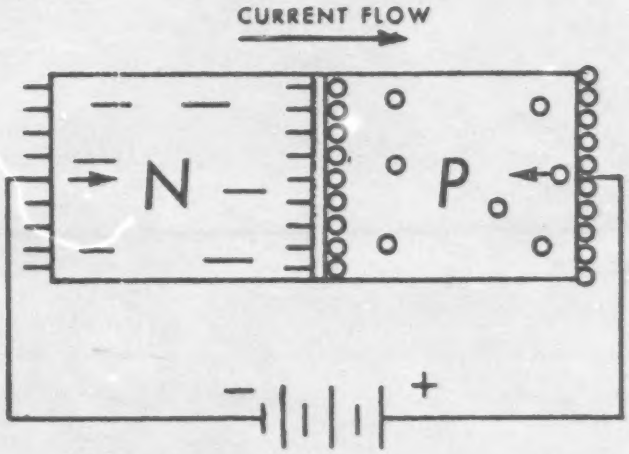
1. The voltage used to adjust the current flow through a PN junction is called _____ voltage.

2. When P-type and N-type materials are joined, the unit formed is known as a _____.

Answers to frame 10: 1. bias 2. PN junction

FRAME 11

Forward bias is a voltage placed on the PN junction in such a way that it aids current flow. The sketch below shows how forward bias is placed on a PN junction. Notice that the negative pole of the source voltage is put on the N-type material and the positive pole is put on the P-type material. This type of bias will cause the like charges to be repelled toward the center. The repelling action of the like charges will decrease the size of the potential barrier. When the barrier has been decreased enough current will flow across the junction.



FORWARD BIAS

Fill in the blanks to complete the following statements.

1. When applying forward bias, the positive pole of the power source is connected to the _____ (negative/positive) material.

2. When forward bias is applied, the width of the potential barrier _____

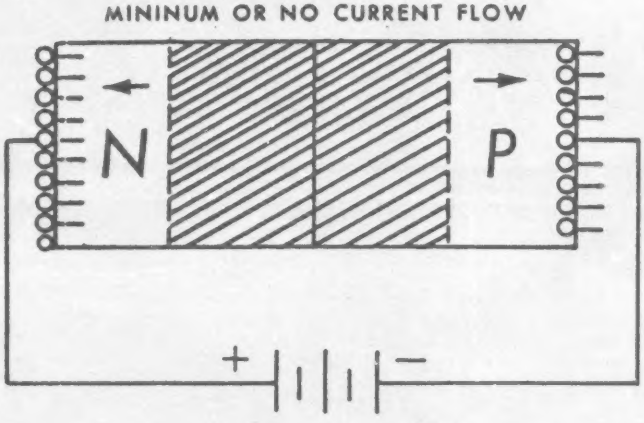
3. Current flows through a PN junction when _____ bias is applied.

1118

Answers to frame 11: 1. positive 2. decreases 3. forward

FRAME 12

Reverse bias is a voltage applied to the PN junction in such a way that it opposes current flow. The drawing below shows how reverse bias is connected to a PN junction. Notice that the negative pole of the source voltage is connected to the P-type material, and the positive pole is connected to the N-type material. This type of connection causes the electrons in the N-type material to be attracted to the positive pole of the source, and the holes in the P-type material to be attracted to the negative pole of the source. This causes the potential barrier to increase in width and allow little or no current flow across the junction.



REVERSE BIAS

Fill in the blanks to complete the following statements.

1. The width of the potential barrier is increased when _____ bias is applied.

2. Reverse bias is connected to the PN junction so that it will _____ current flow.

3. When applying reverse bias, the negative pole of the power source is connected to the _____ (negative/positive) material.

Answers to frame 12: 1. reverse 2. oppose 3. positive 1119

FRAME 13

When the PN junction is used in an electrical circuit it is called a DIODE. A diode is a two element unit, consisting of an EMITTER and a COLLECTOR. The emitter is the N-type material which emits electrons. The collector is the P-type material which accepts electrons. A diode is used in an electrical circuit to allow current flow in one direction only.

The electrical symbol for the diode is shown in figure A below. Current flow is always against the arrow. Figures B and C shows how bias effects current flow in the diode.

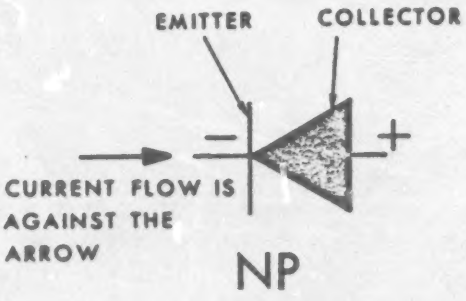


Figure A

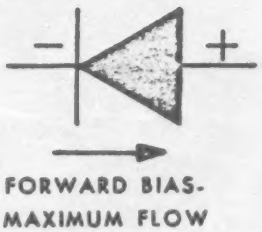


Figure B

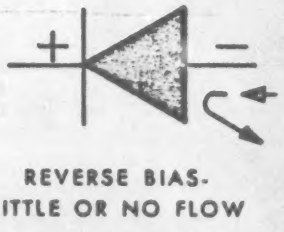


Figure C

Fill in the blanks to complete the following statements.

1. When a PN junction is used in an electrical circuit, it is called a _____.
2. The two elements of a diode are the emitter and _____.
3. A diode is used to allow current flow in _____ _____ only.
4. Current flow through a diode is always _____ the arrow.
5. The N-type material is the _____ (emitter/collector).
6. A diode will _____ current in one direction but will _____ current to flow in the other direction.

1120

Answers to frame 13: 1. diode 2. collector 3. one direction

4. against 5. emitter 6. block, let or allow

FRAME 14

Changing alternating current to direct current is known as RECTIFICATION. When one diode is placed in an AC power supply circuit, it will let current flow on one half of the alternation only. This is called HALF WAVE rectification. For this reason, the diode is called a half wave rectifier.

Now let's trace the current flow in figure A to see how the diode rectifies it. On one half cycle (note arrow 1), the diode is forward biased. Current flow is from negative, through the load, through the diode, and back to positive. On the other half cycle (note arrow 2), the diode is reverse biased. Current will try to flow from the negative to the positive, but it cannot get through the diode. Remember, current only flows through a diode when it is forward biased. Therefore, the load (light) does not burn steadily, but will flash (pulsate) every half cycle. Note in figure B, the sine wave for the AC input as compared to the pulsating DC output.

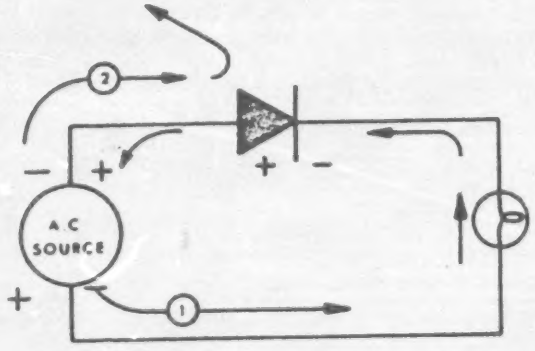


Figure A

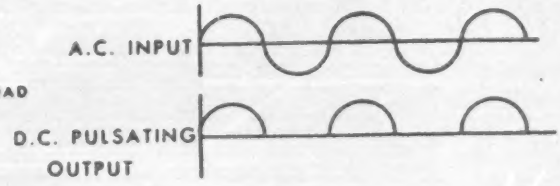


Figure B

Fill in the blanks to complete the following statements.

1. When one diode is used in an AC circuit, it is called a _____ wave rectifier.

2. A half wave rectifier changes alternating current to _____ direct current.

1142

Answers to frame 14: 1. half 2. pulsating

FRAME 15

To change AC to a continuous DC output requires a FULL WAVE rectifier. By using either two or four diodes, the alternating current can be rectified to provide an almost continuous direct current. Let's trace the path of current flow through the circuit in figure A. On one half cycle, diodes 1 and 2 are forward biased, while diodes 3 and 4 are reverse biased. When the source is negative at point A, the current flows through diode 1, then through the load, through diode 2, and back to the positive potential at the source. On the other half cycle, diodes 3 and 4 become forward biased and diodes 1 and 2 become reverse biased. Now current flows from the negative potential at point B, through diode 3, through the load, through diode 4, and back to the source.

With the full wave rectifier in figure A, there is a continuous flow of current through the load. Notice that this current flow is always in the same direction. Compare the sine waves of the AC input to the DC output shown in figure B. A filter network consisting of capacitors, coils and resistors would be used to smooth out the DC ripple effect of figure B. Note in figure C the output effect using capacitors, coils and resistor arrangement.

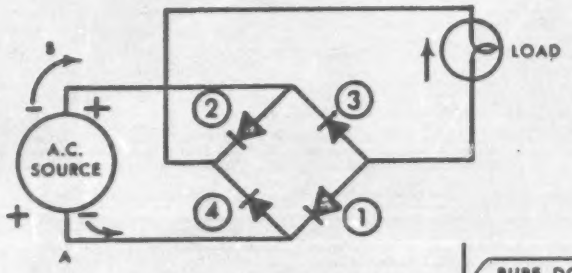


Figure A

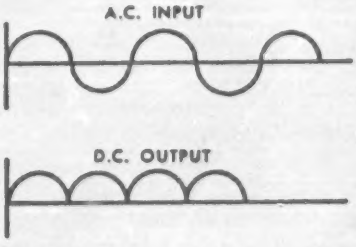


Figure B

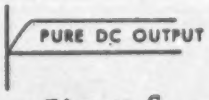


Figure C

Fill in the blanks to complete the following statements.

1. When four diodes are used in an AC circuit, it is called a _____ wave rectifier.

2. A full wave rectifier will allow current flow through the load during _____ (one/both) half cycles.

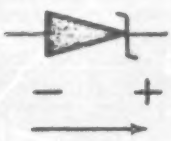
3. When a full wave rectifier is used, the current flow through the load is in the _____ direction.

1122

Answers to frame 1: full 2. both 3. same

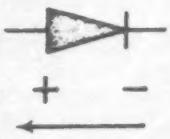
FRAME 16

A ZENER Diode is a special kind of diode specifically designed for use as a voltage regulator. The schematic symbol for a Zener diode is shown in figure A below. On this illustration you will note that current flow is in the opposite direction to that of the normal diode as shown in figure B. Current flow in a Zener diode is with the arrow point. The Zener diode when hooked in a circuit will not allow the electrical circuit to be completed until it absorbs a certain preset voltage. By this token we say the Zener diode in reality is a voltage regulator.



Zener Diode
Current Flow

Figure A



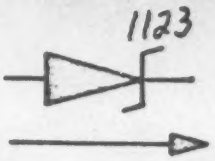
Normal Diode
Current Flow

Figure B

Fill in the blanks to complete the statements.

1. Zener diodes are used as _____ regulators.
2. Current flow in a Zener is (with/against) the arrow.
3. Draw an arrow under the schematic symbol which shows the direction of current flow.

Answers to frame 16: 1. voltage 2. with 3.



FRAME 17

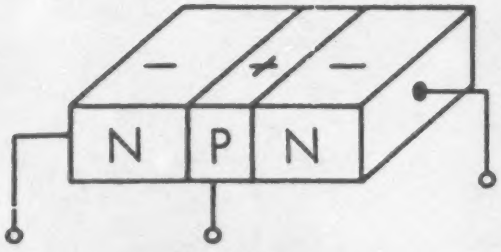
Match the terms given in column B with the statements listed in column A. Place the letter that identifies the correct term in the blank provided. Column B has more responses than needed. Select only one for each question.

A	B
1. The device used as a voltage regulator is a _____.	A. Rectifier
2. When reverse bias is applied to a PN jucntion, it results in _____.	B. AC voltage
3. Biasing a PN junction effects the width of the _____.	C. Reverse bias
4. A circuit that changes AC to pulsating DC is a _____ circuit.	D. Forward bias
5. To have current flowing through a diode requires _____.	E. Potential barrier
6. The part (material) of the diode that serves as the collector is the _____.	F. N-type material
7. When forward bias is applied to a diode, it results in _____.	G. P-type material
8. The part (material) of the diode that serves as the emitter is the _____.	H. Zener diode
	I. Maximum current flow
	J. Minimum current flow

Answers to frame 17: 1. H 2. J 3. E 4. A 5. D 6. G
7. I 8. F

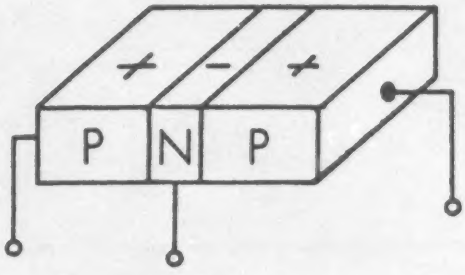
FRAME 18

Thus far the PN junction diodes have been described. These diodes consisted of P-type and an N-type material. When another N or P-type material is added to the diode, it becomes a triode (three element) TRANSISTOP. In modern day electronics, transistors are primarily used as amplifiers and relays. They are replacing vacuum tubes and conventional relays. The reason is that transistors are smaller and lighter than tubes or relays. They also have no moving parts to wear out from excessive use. Thus, the transistor's life span is longer. The two basic types of transistors are NPN and PNP. The block symbol for each is shown in figure A and B below.



Block Symbol for an NPN Transistor.

Figure A



Block Symbol for a PNP Transistor.

Figure B

Fill in the blanks to complete the following statements.

1. A combination of three N and P materials joined together forms a _____.

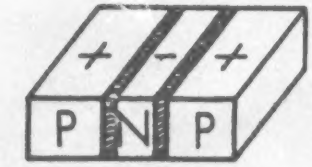
2. Transistors can be used as amplifiers or _____.

Answers to frame 18: 1. transistor 2. relays

FRAME 19

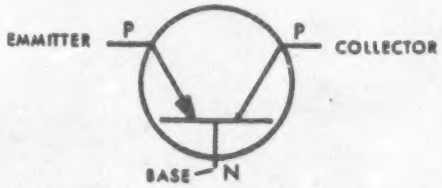
Both NPN and PNP transistors are used in temperature control systems. The PNP transistor consists of two end sections of P material and one center section of N material. These materials are bonded together to form one device. In this process we actually have two PN junctions. This also forms two potential barriers, a potential barrier between each of the PN junctions. Note the barrier regions in the block symbol shown in figure A below.

When a PNP transistor is used in an electrical circuit it is identified by the symbol shown in figure B.



BLOCK SYMBOL OF A PNP

Figure A



ELECTRICAL SYMBOL OF A PNP

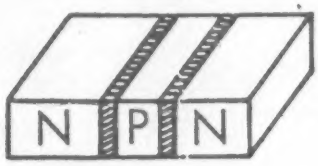
Figure B

NO RESPONSE REQUIRED

The NPN transistor consists of two end sections of N material and one center section of P material. This is shown in figure A. Note that this also forms two PN junctions and two potential barriers.

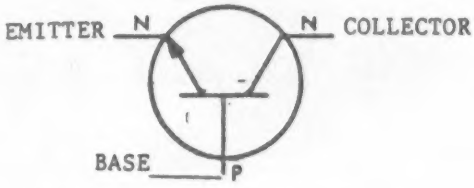
Figure A is the block symbol for an NPN transistor. However, when an NPN transistor is used in an electrical circuit, it is identified by the symbol shown in figure B.

The theory of operation of PNP and NPN transistors is basically the same. In the remainder of this text we will limit our discussion to the NPN transistor. The NPN transistor is the type used in most environmental system control circuits.



Block Symbol of an NPN.

Figure A

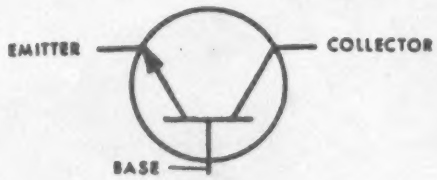


Electrical Symbol of an NPN.

Figure B

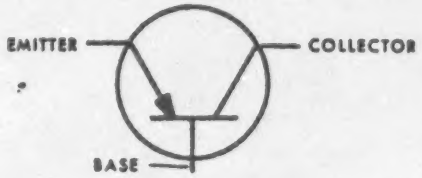
NO RESPONSE REQUIRED

Electrical diagrams of equipment using transistors will contain only the electrical symbol for transistors. The words or letters that identify the emitter, base, and collector are not used. Therefore, it's important that you can identify the sections of a transistor by the electrical symbol only. The arrow in the symbol is the key. The arrow always identifies the emitter. It also tells you whether it's an NPN or PNP. Notice in figure A (NPN transistor) that the arrow points out. Then notice in figure B (PNP transistor) the arrow points in. If the arrow is NOT POINTING IN, it's an NPN transistor. The center section is the BASE, and the remaining section is the COLLECTOR.



Electrical Symbol for an NPN Transistor.

Figure A



Electrical Symbol for a PNP Transistor.

Figure B

Fill in the blanks to complete the following statements.

1. The three sections of a transistor are called _____, _____, and _____.

2. The section of a transistor that controls the current flow through it is called the _____.

3. In the electrical symbol of a transistor, the emitter is signified by an _____.

4. In an NPN transistor, the first N is the emitter and the second N is the _____.

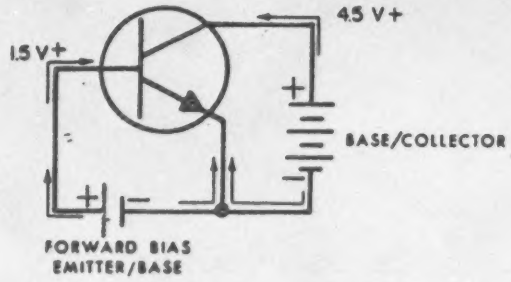
1128

Answers to frame 21: 1. base emitter collector 2. base 3. arro

4. collector

FRAME 22

Having learned that a transistor has an emitter, base, and collector, we can now talk about how it works. There must be a positive signal put on the base, a negative signal put on the emitter, and a positive signal put on the collector. These are shown in the sketch below. With these signals, the transistor is forward biased. As you recall from frame 10, bias is a voltage that is used to fix or set the current flow in a circuit. The sketch below shows the biasing of a transistor. Note that the emitter is pure negative while the base is 1.5 volts (+) positive. The collector circuit has a (+) positive voltage potential of 4.5 volts. It could be said that in order to forward bias the NPN transistor the emitter must be (-) negative, the base (+) positive and the collector at an even higher (+) positive potential.



For the transistor to conduct, forward bias is always applied between the emitter and base.

Fill in the blanks to complete the following statements.

1. Forward bias is always applied between the _____ and _____.

2. A transistor is forward biased when the positive signal is applied to the _____.

Answers to frame 22: 1. emitter base 2. base 1129

FRAME 23

The signal put between the base and emitter controls the current flow that goes from the emitter to the collector. When the signal put on the base is more positive than the emitter, the transistor is forward biased. This will reduce the potential barrier and allow current to flow from the emitter to the collector. Figure A shows the transistor forward biased. Current flows from the negative emitter to the positive base. However, because the collector is always more positive than the base, most of the current flows through the base to the collector.

In figure B, the bias signal to the base is negative in respect to the emitter. This is a reverse bias. This negative signal (reverse bias between the base and emitter) will increase the potential barrier and stop current flow through the emitter-collector circuit. When biasing an NPN or PNP (forward or reverse) you bias the transistor between the emitter and base.

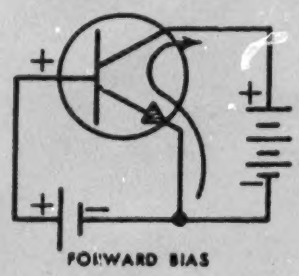


Figure A

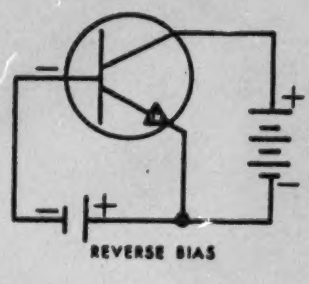


Figure B

Fill in the blanks to complete the following statements.

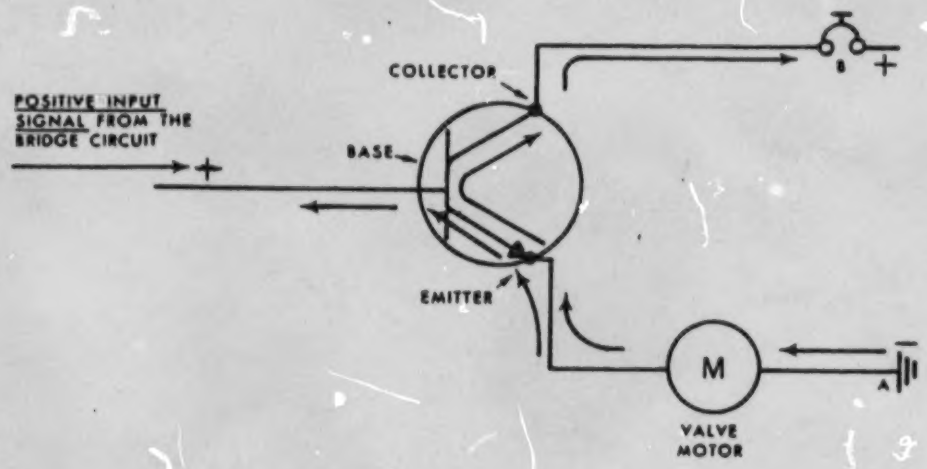
1. Current flows across a transistor only when the base is _____.
2. With a negative signal applied to the base, current flow across the transistor _____.
3. Current flow through a transistor is controlled by the signal applied between the emitter and _____.
4. When forward biasing an NPN transistor, you would bias it between the _____ and _____.

1130

Answers to frame 23: 1. positive 2. stops 3. base
4. emitter and base

FRAME 24

This sketch shows how a transistor is used as a RELAY. The bridge circuit has put a positive signal on the base of the transistor. This will increase the forward bias of the emitter-base circuit. With this increase in forward bias, the transistor will conduct. With the transistor conducting, a circuit is completed between ground (point A) and the circuit breaker (point B). Current flows from ground, through the transistor, to the positive source at point B. When the transistor is conducting, the valve motor runs. When the bridge signal changes to negative, the base of the transistor also becomes negative. This will increase the reverse bias and the transistor will stop conducting. The current flow in the motor will now stop and the motor will no longer run. In this circuit, the transistor is used as a relay to control the operation of the motor.



Fill in the blanks to complete the following statements.

1. When the forward bias is increased the motor will _____.
2. The transistor will not conduct when the base is _____.
3. When a transistor is used to control a motor circuit, it is being used as a _____.

Answers to frame 24: 1. operate 2. negative 3. relay 1131

FRAME 25

Match the terms given in column B with the statements listed in column A. Place the letter that identifies the correct term in the blank provided.

A	B
1. For current to flow through an NPN transistor, a positive signal must be applied to the _____.	A. Triode transistor
2. A transistor can be used as a____.	B. NPN
3. A transistor will conduct when there is ____ between the base and emitter.	C. Emitter
4. When using an electrical symbol of a transistor, if the arrow is pointing away from the base, it is a/an _____ transistor.	D. Base
5. The emitter of a transistor is identified on the electrical symbol by the _____.	E. Collector
6. The solid state device that contains three elements is a _____.	F. Arrow
	G. Forward bias
	H. Reverse bias
	I. Relay
	J. PNP

Name the sections of the transistor shown below:

7. _____

8. _____

9. _____

10. The transistor shown in the above illustration is (a PNP/an NPN).

Answers to frame 25: 1. D 2. I 3. G 4. B 5. F

6. A 7. emitter 8. base 9. collector

10. NPN

Technical Training

Aircraft Environmental Systems Mechanic

MAGNETIC AMPLIFIERS

14 July 1970

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes Service Test 3ABR42231-PT-205, 3 April 1970 and Programmed Text 3ABR42231-PT-205, 9 July 1969.
OPR: TSDS
DISTRIBUTION: X
TSDS - 500; TSOC - 2

Designed For ATC Course Use

FOREWORD

This programmed text has been prepared for use in Course 3ABR42331, Environmental Systems Mechanic. The material contained herein has been validated with 30 students from the subject course. 28 of the students achieved the objectives as stated. Average time for completion of the text is 4 hours and 15 minutes.

OBJECTIVES

After completion of this programmed text, each student will be able to:

1. Apply bridge circuit principles to the magnetic amplifier temperature control.

2. Apply the principles of magnetism to the magnetic amplifier.

   a. Effect of aiding and opposing magnetic fields.
   b. Application of the left hand rule.

3. Describe the functions of the magnetic amplifier windings.

   a. Identification of each winding.
   b. Purpose of each winding.
   c. Effect of each winding in the circuit.

4. Trace the signal for operation of a magnetic amplifier.

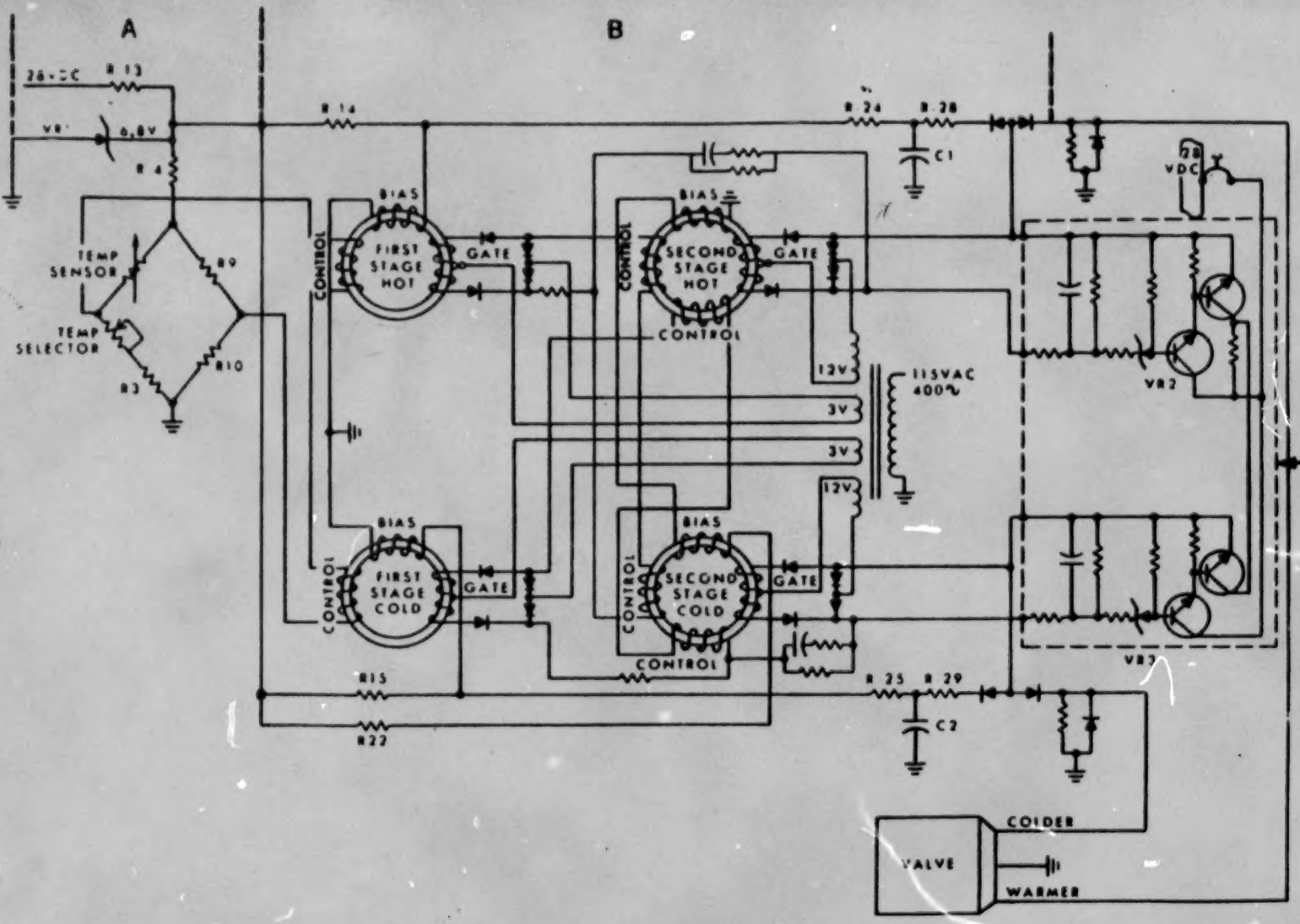
Standard of performance:

The student will demonstrate his knowledge of the objectives by correctly answering 11 out of 15 questions.

INSTRUCTIONS

This text presents material in small steps called "frames." After each frame you are asked to make a response. Read the material carefully before you respond. The answers to the responses for each frame are located at the top of the following page. If you select the correct answers, continue to the next frame. If you are incorrect, read the material again and correct yourself before continuing.

Note: This text is used in conjunction with an overlay transparency. If you do not have this transparency, ask your instructor for it.



Magnetic Amplifier Air Temperature Control.

INTRODUCTION

In the previous lessons on air conditioning systems, we discussed how the air temperature is controlled by positioning the temperature control valve. You should recall that the position of the temperature control valve can be controlled manually by the pilot or automatically by the temperature controller. During automatic operation, the temperature controller positions the valve as a result of signals sent by the bridge circuit. But, how does this signal from the bridge circuit actually control the temperature control valve? That's what we shall be discussing in this text.

In this programmed text we will discuss one type of temperature controller, the magnetic amplifier. The illustration on the opposite page shows the complete magnetic amplifier temperature control system. The area labeled "A" is the bridge circuit, the area labeled "B" is the magnetic amplifier section, and the area labeled "C" is the transistor circuit. As you study this text, you will learn how the signal goes from the bridge, to the magnetic amplifiers, then to the transistors. The transistors control the turbine bypass valve. In the previous lessons, the valve that controlled temperature was called the temperature control valve. In this system it is called the turbine bypass valve. Its purpose is still the same, that is, it will direct the bleed air either into or around the turbine.

Study the diagram and identify the various components. From previous lessons you should recognize the symbols for the power transformer, the various diodes and transistors, and the Zener diodes (VR-1, VR-2, and VR-3). The donut shaped units in section "B" are the magnetic amplifiers. As you study the text, each component and its function in the circuit will be explained. We will take a hot signal from the bridge circuit and follow it until it causes the turbine bypass valve to operate.

FRAME 1

In an automatic temperature control circuit that uses the signal from a bridge, the signal must be amplified (made stronger) before it can control the operation of a temperature control valve. This is the purpose of the magnetic amplifier. It will increase this small signal from the bridge circuit until the signal is strong enough to actuate a relay or cause a transistor to conduct. Magnetic amplifiers are used for this purpose because they are small, have no moving parts, and give off very little heat. These are important factors for an aircraft component.

> Note: In some texts, the electrical signal from the bridge circuit is called an "error signal." This is because it is signalling the system that there is an error in temperature that needs correcting. However, throughout this text we will refer to the signal from the bridge as simply the "signal."

Fill in the blanks to complete the following statements.

1. The purpose of a magnetic amplifier is to take a _____ signal and make it stronger.

2. The magnetic amplifier receives the signal from the _____ circuit.

3. Advantages of the magnetic amplifier are; they are small, have no moving _____, and give off _____ _____ _____.

Answers to Frame 1: 1. small or weak 2. bridge 3. parts very little heat

FRAME 2

A magnetic amplifier works on the principle of magnetism, so let's review some principles of magnetism.

Magnetic poles that are alike (N to N or S to S) will repel or oppose each other. Unlike magnetic poles (N to S or S to N) will attract or aid each other. If the magnetic field is created by an electromagnet, that is, by a coil winding, then the magnetic field will have a direct affect on the current flow through the wires of the coil winding. When two coils are used on the same core, if current flows through the windings of both coils in the same direction, they will have like magnetic poles and will oppose each other. If the current flows in one direction through one coil and the opposite direction in the second coil, they will have unlike, or opposite, magnetic poles and will aid each other. This aiding or opposing of magnetic poles will also aid or oppose current flow through the coil. This is an important point in understanding the operation of a magnetic amplifier.

Fill in the blanks to complete the following statements:

1. Unlike magnetic poles will _____(aid/oppose) each other.

2. If current flows in the same direction through two coils that use the same core, the magnetic poles will _____ (aid/oppose) each other.

3. If current flows in opposite directions through two coils that use the same core, the magnetic poles will be _____ (alike/unlike) and will _____ (aid/oppose) current flow through the windings.

1139

Answers to Frame 2: 1. aid 2. oppose 3. unlike aid

FRAME 3

Tracing current flow through the magnetic amplifier requires us to determine the magnetic polarity of various coils. To do this we must use the left hand rule. The way to use the left hand rule is illustrated below. If you grasp the coil with your left hand so that your fingers follow the coil windings and current flow through the windings, your thumb will point toward the North pole. The other end of the coil is the South pole. This is how you can determine all of the magnetic poles of the windings in a magnetic amplifier. After you determine the magnetic polarity of the windings, then you can determine if the windings aid or oppose each other. This also allows you to determine if current will flow through the winding.

Left-Hand Rule.

Fill in the blanks to complete the following statements.

1. Magnetic poles of all the windings in a magnetic amplifier can be determined by using the _____ _____ _____.

2. When using the left hand rule, your thumb will point to the _____ pole.

3. When using the left hand rule, your fingers should follow the _____ flow through the windings.

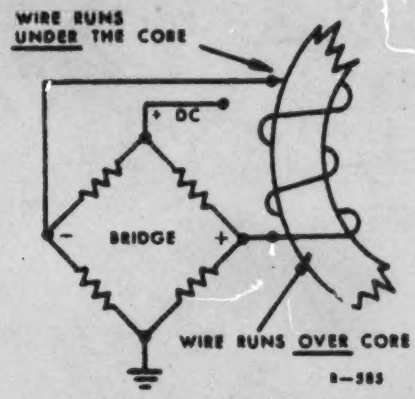
1162

Answers to Frame 3: 1. left hand rule 2. north 3. current

FRAME 4

When using the left hand rule, be sure that you follow the wire around the core correctly. If you don't the magnetic poles that you determine will be incorrect. The illustration below shows how a wire runs over or under a core. When using the left hand rule, be sure your fingers are following current flow from negative (-) to positive (+) and they should run either over or under the core the same way the wire does.

Determine the polarity of the coil in the illustration:

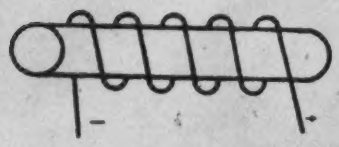


Determining Coil Polarity.

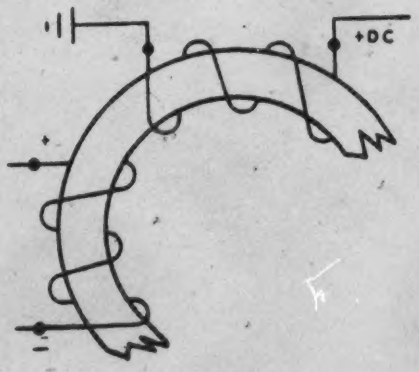
If you determined that north is at the top and south is at the bottom, you are correct.

Draw in the magnetic poles for each illustration.

1.



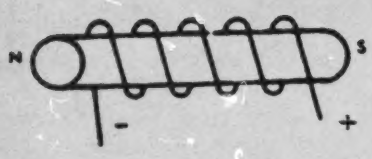
2.



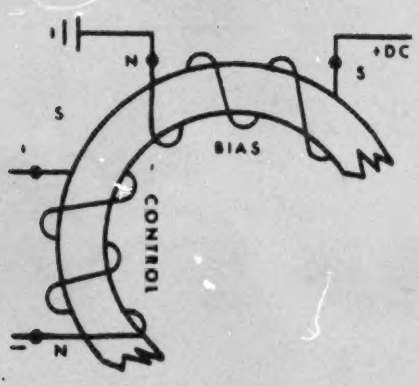
1141

Answers to Frame 4:

1.



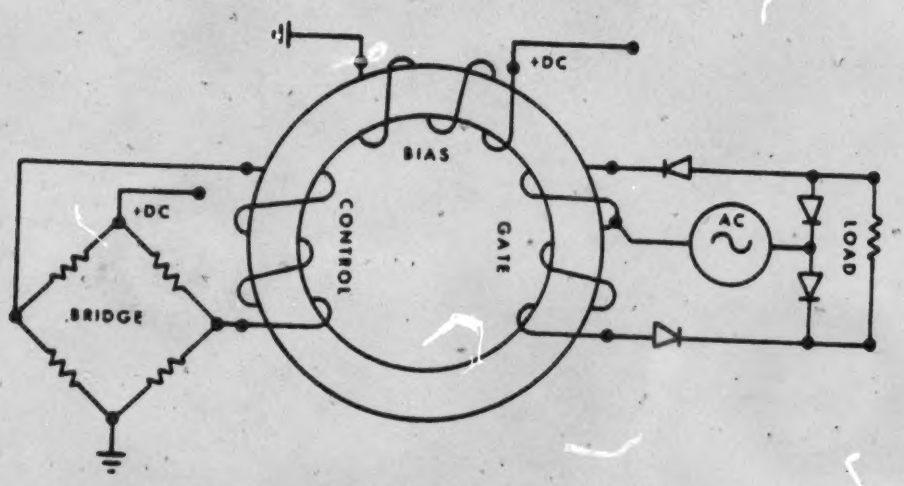
2.



FRAME 5

A basic magnetic amplifier contains a metal core, shaped like a donut, with wire coils wound around the core. The core is a material that can be easily magnetized. The core is circular (donut) shaped because this design provides a better magnetic field.

The diagram below illustrates a magnetic amplifier with three separate windings. These are, the gate winding, the bias winding, and the control winding. Each of the windings has a specific function in the operation of the magnetic amplifier and in overall operation of the temperature controller. The direction that current flows through the windings is the controlling factor of the magnetic amplifier.

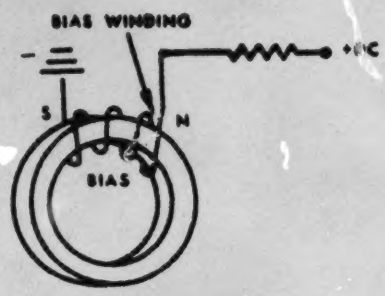


Basic Magnetic Amplifier.

No Response Required

Before tracing the signal through the temperature controller, you need to know the purpose of each of the three windings, how they operate, and how each one affects the other. We'll begin with the bias winding.

The bias winding, illustrated at the right, used direct current (DC) power. This means that current will always be flowing in the same direction through the winding. The polarity of this winding is shown in the illustration. Since power for the bias winding is DC and it's always flowing in the same direction, then the magnetic polarity will always be the same. The purpose of the bias winding is to establish a fixed control point at which the gate winding can be triggered.



Fill in the blanks to complete the following statements.

1. The windings in a magnetic amplifier are wound around a _____ core.

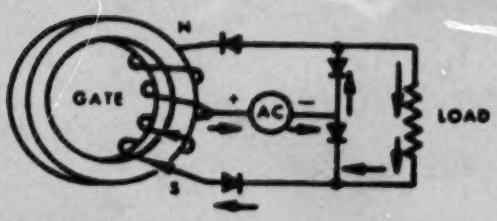
2. The bias winding operates on _____(AC/DC) current.

3. The magnetic poles of the bias winding will always be the gate winding because the _____flow is always in the same direction.

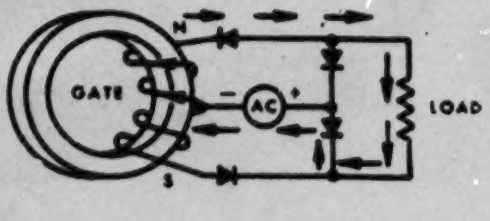
Answers to Frame 6: 1. metal 2. DC 3. same current

FRAME 7

The gate winding controls power from the amplifier to the load. The power supply for this winding is from an AC (alternating current) source. However, the current flow through the windings is DC. The AC current from the source is rectified by diodes. In illustration "A" note the four diodes. Arrows have been drawn on this diagram to illustrate the path of current flow for one alternation of the AC power. Trace the current flow by following the arrows and determine the polarity of the gate winding by using the left hand rule. Also note the direction of current flow through the load.



A



B

Illustration "B" shows the second alternation of the AC power source. Again, arrows are drawn on the diagram to illustrate the path of current flow. Trace the current and determine the polarity of the gate winding for this alternation. Has the polarity changed? Did the direction of current flow through the load change? The polarity remained the same and the direction of current flow through the load remained the same.

Fill in the blanks to complete the following statements.

1. The gate winding controls power from the amplifier to the _____.

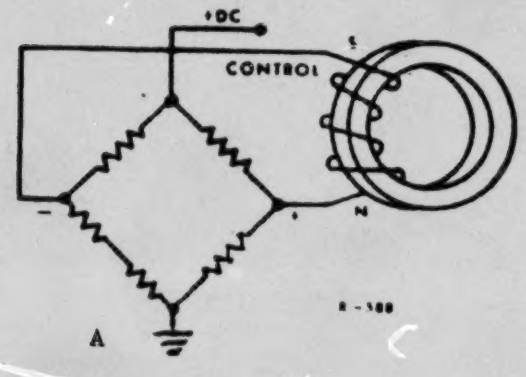
2. Diodes are used in the gate winding circuit to change _____ to _____.

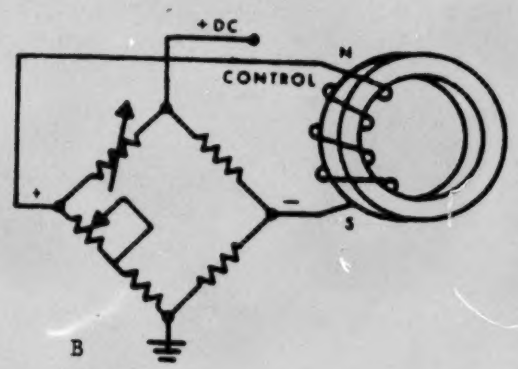
3. Current flow through the _____ winding and the load will be in the same _____.

Answers to Frame 7: 1. load 2. AC DC 3. gate direction

FRAME 8

The control winding takes the signal from the bridge circuit and, using this signal, controls the gate winding. The signal from the bridge is in the form of DC current. When the negative and positive points of the bridge are as shown in illustration "A", current will flow through the control winding and cause the magnetic poles of the windings to be as illustrated.





However, should the resistance in one leg of the bridge change, the negative and positive points of the bridge will reverse as shown in illustration "B". Now current will flow through the control winding in the opposite direction. What will happen to the magnetic polarity of the control winding? It will also reverse.

The resistance of the sensor or selector will determine the direction of current flow from the bridge. This will, in turn, determine the direction of current flow through the control winding. Remember, the polarity of the winding depends on the direction of current flow.

Fill in the blanks to complete the following statements.

1. The control winding uses _____ (AC/DC) current.

2. The magnetic poles of the control winding are determined by the signal from the _____ _____.

3. The magnetic poles of the _____ winding will change with the _____ of current flow from the bridge circuit.

Answers to Frame 8: 1. DC 2. bridge circuit 3. control direction

FRAME 9

REVIEW QUIZ

1. A magnetic amplifier uses a small signal from the _____ _____ to control a larger signal.

2. Magnetic poles that are alike (N to N) will _____ each other and oppose _____ flow.

3. When using the left hand rule, your thumb will point to the _____pole.

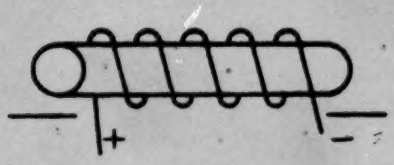
4. The signal from the bridge circuit determines the polarity of the _____ winding.

5. In the gate winding circuit, the AC current is changed to a DC current by the _____.

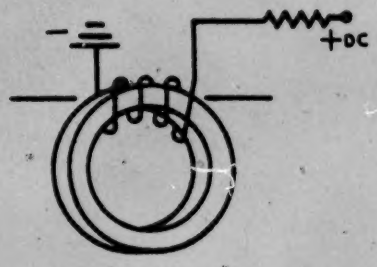
6. The current flow through the lead is _____(AC/DC).

Determine the north (N) and south (S) poles of each of the following windings and write N or S in the space provided.

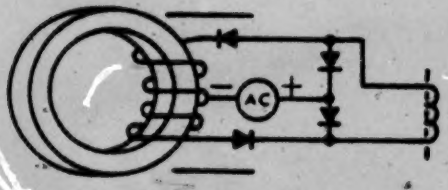
7.



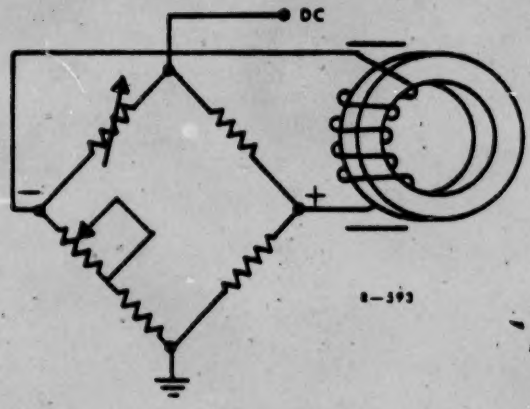
8.



9.



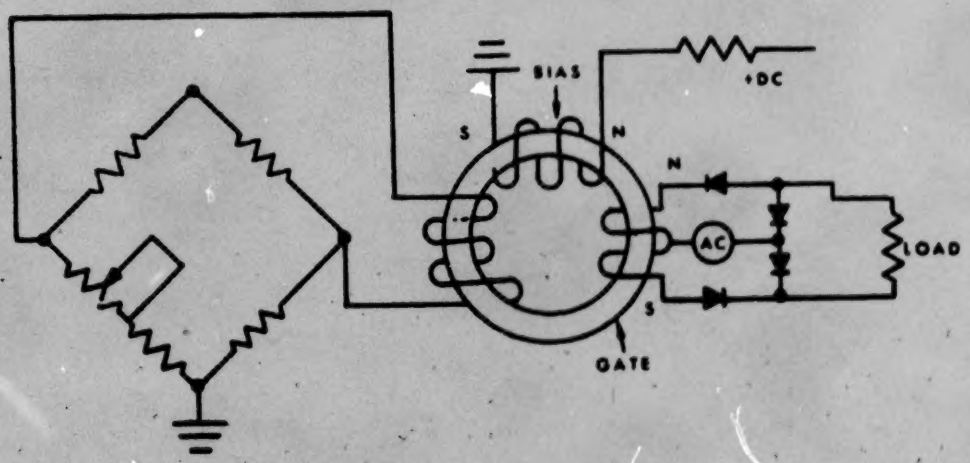
10.



Answers to Frame 9: 1. bridge circuit 2. repel current 3. north
4. control 5. diodes 6. DC 7. S N 8. S N 9. N S 10. S N

FRAME 10

Now let's see how the polarities of one winding effects the other winding. Remember, the polarity in the bias winding is always the same and the polarity of the gate winding is always the same. Polarity of the control winding depends on the bridge circuit. Note in the illustration below that the bias winding and the gate winding have like poles. This means they will always oppose each other. The current flow through the bias winding will oppose current flow through the gate winding.



Fill in the blanks to complete the following statements.

1. The bias winding and gate windings have _____magnetic poles.

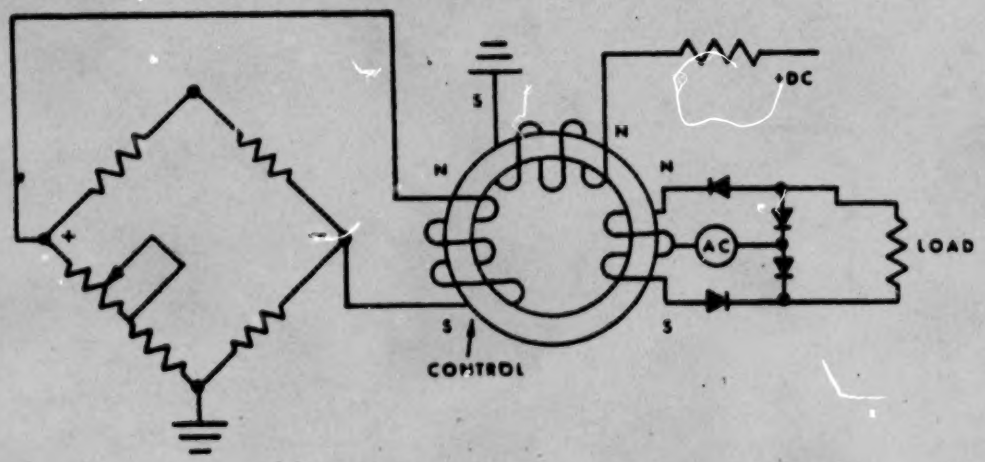
1. The bias winding will always _____current flow through the gate winding.

1147

Answers to Frame 10: 1. like 2. oppose

FRAME 11

Since the polarity of the control winding can change, depending on the direction of current flow from the bridge, it will either aid or oppose the gate winding. When the magnetic poles of the control winding are as illustrated below it will oppose current flow through the gate winding. Note that the poles are alike. When the magnetic poles are as illustrated, the bias winding and the control winding are both opposing the gate winding. This opposition will reduce current flow in the gate winding. This will also decrease current flow to the load.



Fill in the blanks to complete the following statements.

1. The control winding can either _____ or _____ the gate winding.

2. When the magnetic poles of the control and gate winding are alike, current flow through the gate will _____.

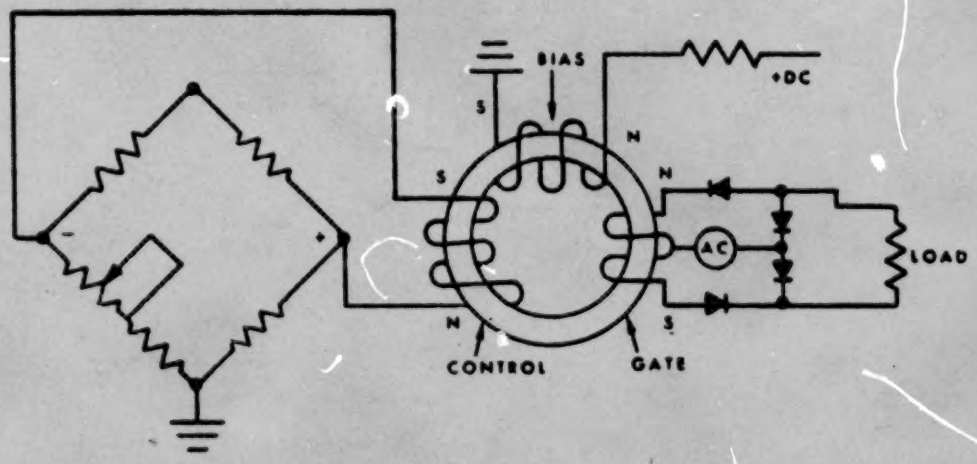
3. The signal from the bridge circuit determines the polarity of _____ winding.

1170

Answers to Frame 11: 1. aid oppose 2. decrease 3. control 1148

FRAME 12

When the direction of current flow from the bridge changes, the direction of current flow through the control winding will also change. This will change the magnetic polarity of the control winding. When the magnetic poles of the windings are as illustrated below, the control winding will aid the gate winding. Notice the gate winding and control winding have unlike poles. Remember, unlike poles will aid each other. By aiding the gate winding there will be less opposition to current flow. This will result in an increase in current flow through the gate winding and through the load.



The gate winding controls the electrical signal that will cause the load to operate. If the gate winding is aided by the control winding the load will operate. If the gate winding is opposed by the control winding, the load will not operate.

Fill in the blanks to complete the following statements.

1. When the direction of current flow from the bridge changes, the magnetic poles of the _____ winding will also _____.

2. Current will flow through the load when the control winding is _____ (aiding/opposing) the gate winding.

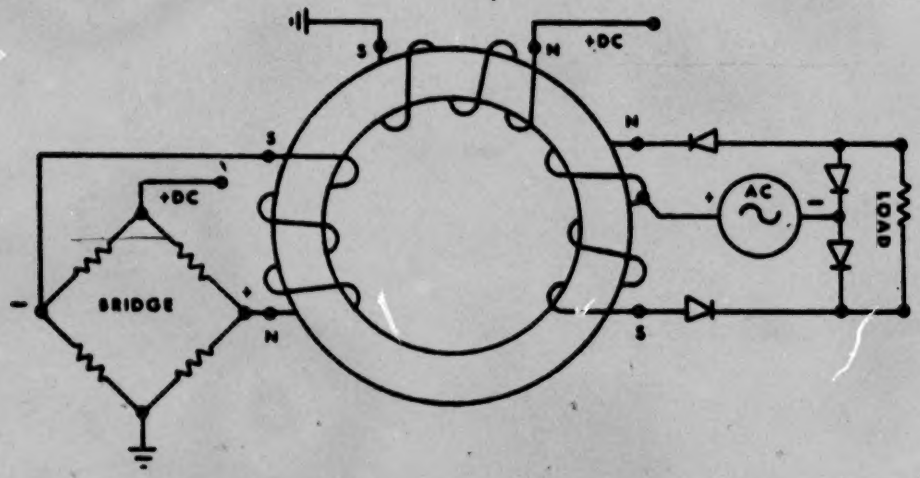
3. The control winding aids the gate winding when the magnetic poles are _____ (like/unlike).

1149

Answers to Frame 12: 1. control change 2. aiding 3. unlike

FRAME 13

Let's see how the magnetic amplifier operates with a signal from the bridge. In the illustration below, the signals from the bridge and AC power source, and the magnetic poles have been drawn in. The North pole of the control winding is facing the South pole of the gate winding. This aids current flow in the gate winding. The bias winding is still opposing the gate winding, but now the aid from the control winding is stronger than the opposition from the bias winding. The rectified AC signal will flow through the gate winding to the load. Current flow through the gate winding will build up until it is strong enough to operate the load. The amount of current flow through the gate winding will depend on the strength of the signal from the bridge.



Fill in the blanks to complete the following statements.

1. When the North pole of the control winding is facing the South pole of the gate winding, current _____ (will/will not) flow through the load.

2. In the circuit illustrated, the bias winding is _____ the gate winding and the control winding is _____ the gate winding.

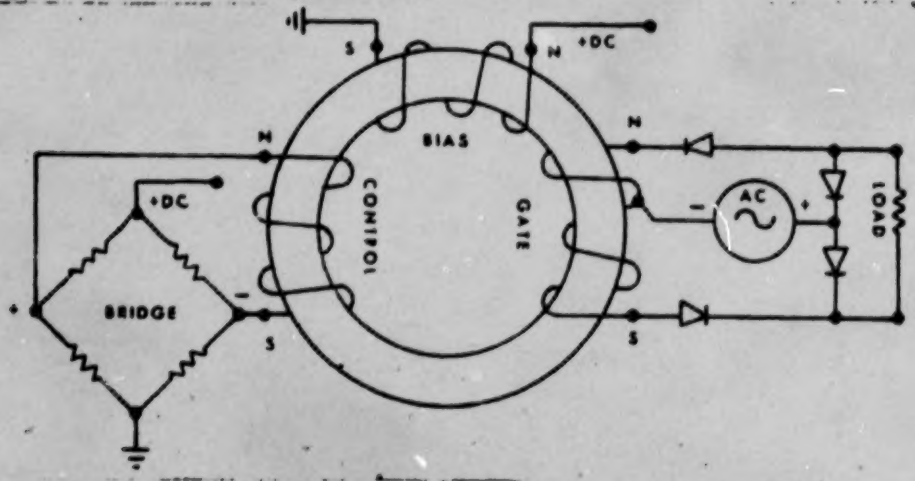
1172

Answers to Frame 13: 1. will 2. opposing aiding 1150

FRAME 14

Let's see what happens to the operation when the signal from the bridge changes to that shown in the illustration below. The control winding has changed magnetic poles because of the change in direction of current flow from the bridge. The South pole of the control winding is facing the South pole of the gate winding. These two poles are repelling each other or opposing current flow. The North pole of the bias winding is facing the North pole of the gate winding, and will also be opposing current flow in the gate winding.

With the control and bias winding both opposing the gate winding there is very little current flow through the gate winding. With this condition, there is not enough current flow to operate the load.



Fill in the blanks to complete the following statements.

1. When the South pole of the control winding is facing the South pole of the gate winding, current _____(will/will not) flow through the load.

2. In the circuit illustrated, the bias winding is _____ and the control winding is _____ the gate winding.

1157

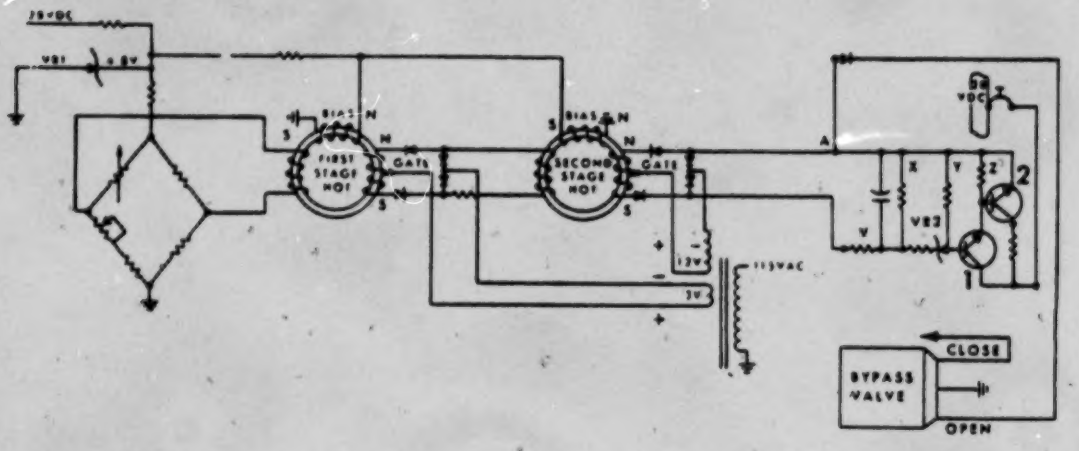
Answers to Frame 14: 1. will not 2. opposing opposing

FRAME 15

Let's see how the magnetic amplifier controls the turbine bypass valve. In the illustration below, we've added a second-stage amplifier, a transistor circuit, and a bypass valve. The illustration shows only the circuit that the hot signal uses.

Because the signal from the bridge is very small, a second stage amplifier is needed to increase the signal for operation of the load. Note that the load for the second stage is the transistors which in turn will operate the bypass valve.

Before we trace a signal through this circuit, let's compare it to the simple magnetic amplifier that we've been discussing. The bias windings of both the first and second stages are connected to the same DC power source. The bridge circuit is still connected to the control winding of the first stage amplifier. But, instead of having the gate winding from the first stage connected to the load, it's connected to the "control winding" of the second-stage amplifier.



Fill in the blanks to complete the following statements.

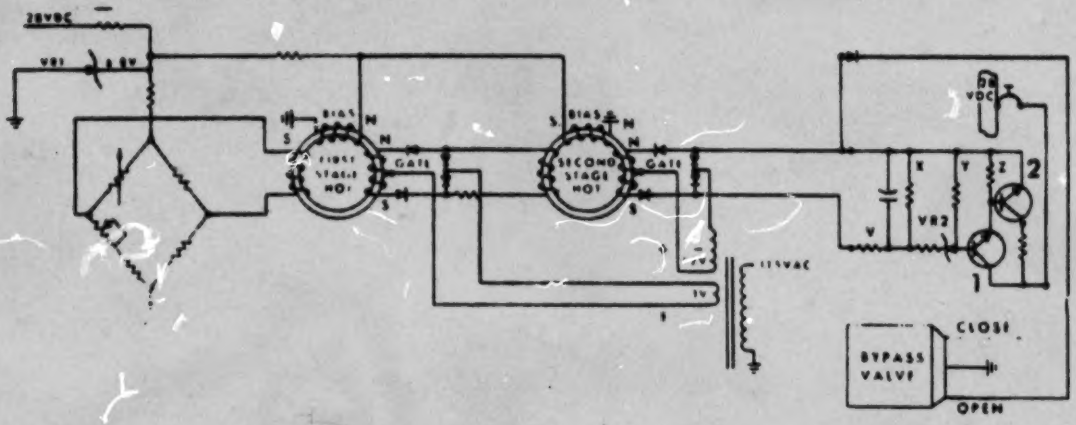
1. The magnetic poles of the bias and gate winding will always _____(aid/oppose) each other.

2. Current flow in the second-stage control winding is controlled by the first-stage _____ winding.

Answers to Frame 15: 1. oppose 2. gate

FRAME 16

The power source for both gate windings is still from an AC power supply. In this circuit, the AC source is a power transformer. The power for the gate windings is taken from the transformer's secondary windings. Notice in the illustration below that power for the first-stage gate winding is 3 volts and the power for the second-stage gate winding is 12 volts. In our discussion, we will refer to the secondary windings as the 3-volt or 12-volt taps. Remember, the current going through the gate windings is actually DC because the AC is rectified by the diodes.



Let's see why the second-stage gate winding uses 12 volts, where the first-stage gate only uses 3 volts. The bridge signal going to the first-stage control winding is very small (or weak). Therefore, it cannot be used to directly operate the transistors. However, it can be used to control the 3-volt gate winding. The 3 volts is then applied to the control winding of the second stage. The 3-volt signal is now strong enough to control the 12-volt signal through the second-stage gate winding. Through the use of the magnetic amplifiers, the bridge signal, which may be less than 1 volt, is amplified to 3 volts, then to 12 volts. The stronger 12-volt signal is required to cause the transistors to conduct.

Fill in the blanks to complete the following statements.

1. The secondary windings of the power transformer provide power for operation of the _____ windings.

2. The reason for using 3 volts in the first-stage gate windings is because the bridge signal is very _____.

3. The purpose of the two stages of amplification is to increase the _____ signal enough to cause the _____ to conduct.

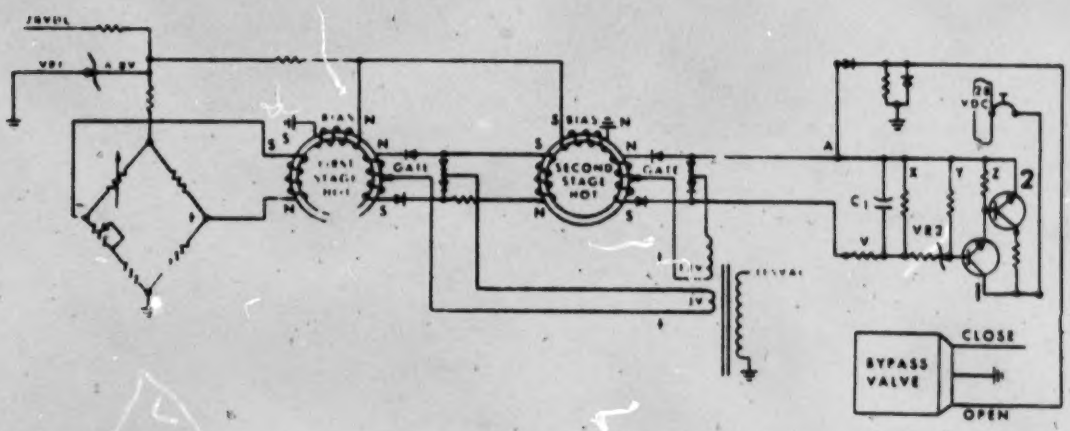
1153

Answers to Frame 16: 1. gate 2. small (weak) 3. bridge transistors

FRAME 17

Let's trace the signal. Looking at the illustration below, note the signals and magnetic poles have been set up so that each control winding is aiding the gate winding. This allows current flow from the 3-volt source to flow through the first-stage gate winding to the second stage control winding. This in turn allows the current from the 12-volt source to flow through the second-stage gate winding.

Follow the path of current flow from the negative (-) side of the transformer 12-volt tap, through the diode to point "A." From point "A" it flows to, and charges, the capacitor (C1). At the same time it sets up a voltage potential at the three resistors marked X, Y, and Z. Resistor X is the normal path for current flow until the Zener diode (VR2) breaks down and starts conducting. Follow this return path through resistor X, through resistor V, through the lower diode at the gate winding, then through the gate winding to the center connection and back to the positive (+) potential at the 12-volt transformer tap. Until the signal becomes strong enough to cause the Zener diode to break down, the current will flow through resistor X. In this condition, the transistors will not conduct.

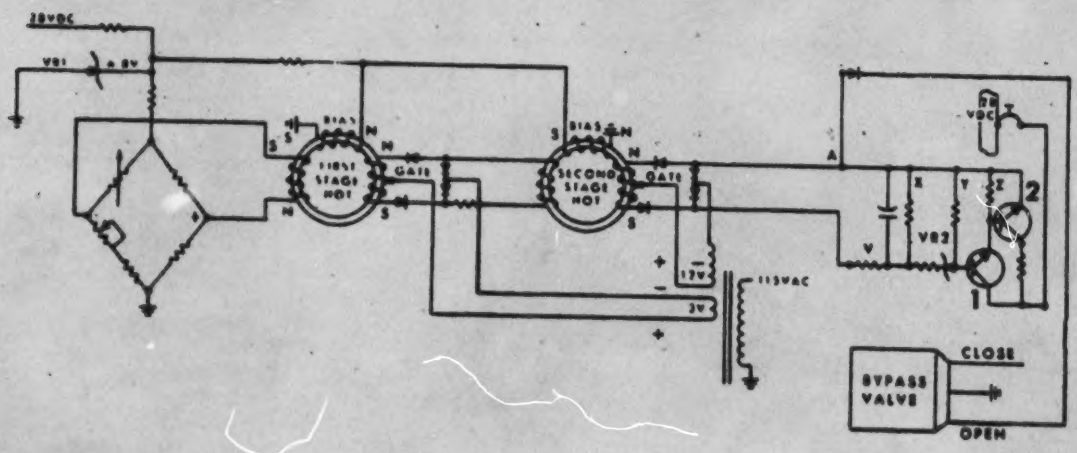


No Response Required

1176

As the signal from the bridge becomes stronger, it increases the strength of the signal through the magnetic amplifier. This will increase the potential across the Zener diode (VR-2) and force it to break down. When the Zener diode breaks down, current flows through resistor "Y," through the Zener diode, then through the second-stage gate winding and to the positive side of the 12-volt tap.

The current flowing through the Zener diode causes the base of transistor #1 to become more positive than its emitter. This will forward bias the transistor and cause it to conduct. Current now flows through resistor Z and transistor #1. The current flow through transistor #1 causes the base of transistor #2 to become more positive than its emitter, causing it to conduct.



Fill in the blanks to complete the following statements.

1. Forward biasing of the trabsistors is controlled by the _____ _____.

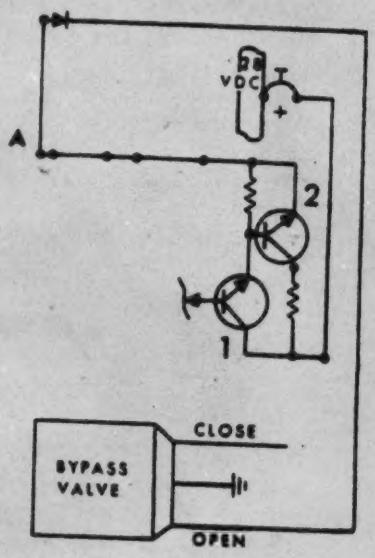
2. The strength of the potential at the Zener diode is a direct result of the signal from the _____ circuit.

1155

Answers to Frame 18: 1. Zener diode 2. bridge

FRAME 19

The transistors actually serve as relays or switches for the bypass valve circuit. The transistors are forward biased when the Zener diode breaks down. This permits current flow from the emitter to the collector of the transistors. Note in the diagram how this will complete a circuit from the bypass valve ground to the 28V DC source. When the transistors conduct, current can flow from the bypass valve ground, through the valve motor winding (hot or open side), through the diode, then through the transistors to the positive potential at the 28V DC circuit breaker. This will operate the valve to the hot (open) position.



Fill in the blanks to complete the following statements.

1. The bypass valve circuit is controlled by the _____.

2. When hot air is demaneded, the bypass valve will operate to the _____ position.

3. The bypass valve will operate to the hot position only when the transistors are _____(forward/reverse) biased.

4. The transistors serve as _____ for the valve circuit.

1178

Answers to Frame 19: 1. transistors 2. open 3. forward 4. switches or relays

FRAME 20

Operation of the transistors is controlled by the Zener diode. That is, when it breaks down it allows the transistors to reduce their internal resistance where they can operate the valve motor. To prevent total breakdown and burnout of the Zener diode, the capacitor mentioned earlier absorbs the rapid charging and discharging when the Zener diode starts conducting.

If we had used a cold signal from the bridge circuit, the signal would have aided the cold magnetic amplifiers. This would have caused the transistors in the cold circuit to conduct. The circuit would have been operated in the same manner, except it would cause the valve motor to operate in the opposite direction, providing cold air. Remember, the bridge circuit signal determines whether the hot or cold amplifiers operate.

Fill in the blanks to complete the following statements.

1. When cold air is demanded, the bypass valve will operate to the _____ (open/closed) position.

2. If the signal from the bridge causes the first-stage hot control winding to oppose the gate winding, and the first-stage cold control winding to aid the gate winding, the bypass valve will _____ (open/close).

Answers to Frame 20: 1. closed 2. close

FRAME 21

REVIEW FRAME

With the signal on the bridge as shown in the illustration below, answer questions 1 through 5.

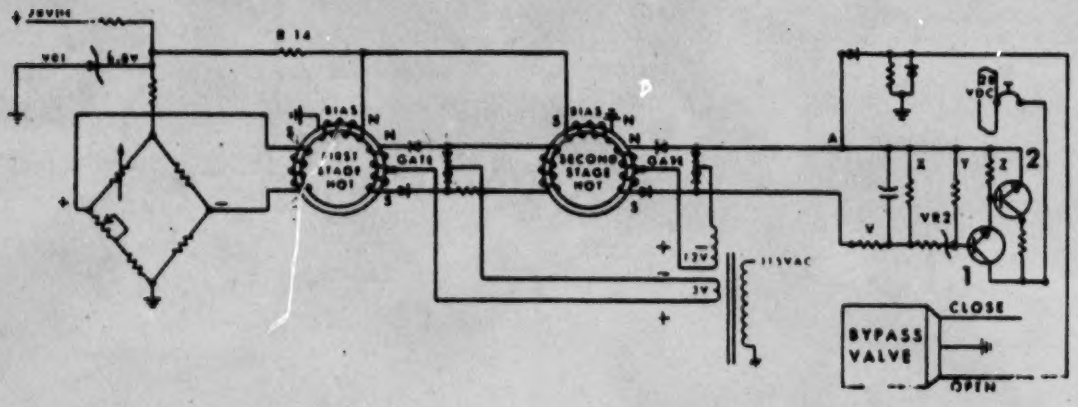
1. Will the first-stage control winding aid or oppose the first-stage gate winding? _____

2. Does the bias winding and gate winding have like or unlike poles? _____

3. Will the second-stage control winding have any current flowing through it? _____

4. Is the second-stage bias winding aiding or opposing the gate winding? _____

5. With the signal as shown, is the voltage potential on the base of the transistors positive or negative? _____



Using the same illustration as a reference, fill in the blanks to complete the following statements.

6. The purpose of the diodes in the gate circuits is to rectify _____ current to _____ current.

7. The valve circuit is completed when the transistors are _____.

8. When the Zener diode breaks down and causes the transistor base to be more positive than the emitter, the transistor is said to be _____ biased.

9. The voltage applied to R-14 of the bias winding circuit is _____ volts DC.

10. The 3-volt tapoffs on the power transformer are the _____ windings of the transformer.

11. When the base of transistor #1 is positive, the base of transistor #2 becomes _____.

12. The Zener diode in the transistor circuit holds back the signal until it is _____ enough to break it down.

Match the items listed in Column "B" with the statements given in Column "A."

	COLUMN A	COLUMN B
13. ____	Aids current flow in the gate winding.	A. Bridge circuit
14. ____	Always opposes current flow in the gate winding.	B. Gate winding
15. ____	Provides the signal to the control winding.	C. Control winding
16. ____	Controls current flow to the load.	D. Transformer
17. ____	Changes the AC current in the gate winding circuit to DC current.	E. Bias winding
		F. Diodes

1159

Answers to Frame 21: 1. oppose 2. like 3. no 4. opposing 5. negative 6. AC DC 7. conducting 8. forward 9. 6.8 10. secondary 11. positive 12. strong 13. C 14. E 15. A 16. B 17. F

Note: For the rest of this lesson, use the overlay transparency provided with the text. If you do not have an overlay transparency, ask the instructor for one. We will use this transparency to trace the operation of the magnetic amplifier type temperature controller.

FRAME 22

In the previous frames we've discussed a basic magnetic amplifier. We've followed a signal from the bridge, through the amplifier and transistors, and caused the valve to operate to the hot position. However, a temperature control system must be able to provide either hot or cold air. The magnetic amplifier must have a hot and a cold amplifier circuit.

Open the overlay transparency until "sheet number 1" is the only sheet showing. This shows the hot and cold first-stage amplifiers. A signal has been placed on the bridge that will call for hot air. By tracing the current flow from negative to positive and using the left hand rule, we can determine the magnetic poles of both control windings. Notice as you follow the circuit from the bridge that current flows through the control winding of the first-stage hot amplifier then continues through the control winding of the first-stage cold amplifier and back to the bridge. But, notice that the control winding on the hot amplifier is wound opposite the control winding on the cold amplifier. What will this do to the magnetic poles? It will cause the magnetic poles to be opposite. In the circuit illustrated, the hot control winding will aid its gate winding and the cold control winding will oppose its gate winding.

Fill in the blanks to complete the following statements.

1. When current flow from the bridge causes the cold control winding to aid its gate winding, the hot control winding will be _____ its gate winding.

2. A magnetic amplifier type temperature controller will have a hot and _____ amplifier circuit.

3. The signal from the bridge will determine the magnetic poles of the _____ and cold _____-windings.

1182

Answers to Frame 22: 1. opposing 2. cold 3. hot control

FRAME 23

Fold sheet 2 over sheet 1. Note that the bias windings are added to the circuit. Also notice that both bias windings have the same negative ground point "A". Current will flow from this ground point through both bias windings at the same time. Current for the hot bias winding will flow through the winding and through resistor R14 to point "B". Current for the cold bias winding will flow through the winding and through resistor R15 and to point "B" also. From point "B", current flows to the 28V DC (+) source. This is the same voltage source that is used for the bridge circuit. Since current is flowing, you can determine the magnetic poles of the bias windings. The direction of current flow through both windings will not change, so the poles will alsways remain the same. Remember, the bias windings always oppose the gate windings.

Fill in the blanks to complete the following statements.

1. The bias windings always _____current flow through the gate windings.

2. Current flow through both bias windings is _____(AC/DC).

3. The poles of both _____windings will always remain the same.

Answers to Frame 23: 1. oppose 2. DC 3. bias

FRAME 24

Fold sheet 3 over sheets 1 and 2. The gate winding circuit is added for both the hot and cold amplifiers. The power for these windings is from the transformer 3-volt tap. Let's start by following current flow through the gate winding of the first-stage hot amplifier. Starting at the negative point of the upper transformer secondary (3-volt) winding, current flows to the middle of the hot gate winding, through the winding and through the diode in this text we will identify them and give their purpose.) From coil 1 current flows to coil 3, then back up to the diode at the hot gate winding circuit and back to the positive potential at the transformer 3-volt tap.

Current will flow in the hot gate winding circuit because the control winding is aiding current flow in this winding. The aid from the control winding will overcome the opposing action of the bias winding.

Since current is flowing in the hot gate winding, the magnetic poles can be determined. You should recall that the current flow through the gate windings is direct current and is always going in the same direction. The magnetic poles will always remain the same.

Fill in the blanks to complete the following statements.

1. Current flow through the gate windings is _____(AC/DC).

2. The purpose of the diodes in the gate winding circuit is to change _____ current to _____current.

3. The power source for the gate winding circuit is from the transformer _____windings.

Answers to Frame 24: 1. DC 2. AC DC 3. secondary

FRAME 25

Let's look at the circuit for the gate windings of the cold amplifier. The path for current flow is from the negative point of the lower 3-volt transformer tap, and from there through the diode and up to coil 2. From coil 2 the circuit goes down through coil 4, through the diode at the cold gate winding, then through the gate winding and out at the center connection and back to the positive potential at the transformer. However, notice in our circuit that the cold gate winding. With the bias and control windings both opposing the gate windings, there will be little, if any, current flow through the cold amplifier gate winding.

We started with a signal for hot air from the bridge, and the hot amplifier is operating and the cold amplifier is shut down. This is because the hot control winding is aiding its gate while, at the same time, the cold control winding is opposing its gate. Remember, the hot and cold control windings are wound so that their poles are reversed.

Fill in the blanks to complete the following statements.

1. Current will flow through the hot gate winding in the circuit illustrated because the _____winding is aiding the _____ winding.

2. Current will not flow through the cold gate winding in the circuit illustrated because the _____winding and _____winding are opposing the _____winding.

Answers to Frame 25: 1. Control gate 2. bias control gate

FRAME 26

Fold over sheet number 4. The second-stage hot and cold amplifiers are added. Notice that coils 1,2,3, and 4 that were part of the first-stage gate winding circuits are really the control windings for the second-stage amplifier. The second-stage amplifiers have two control windings because one winding is used as a positive shutoff for the amplifier that is not operating. This will be explained later in the text.

With the hot signal from the bridge, current will flow in the first-stage hot gate winding. Follow the circuit from the negative point at the 3-volt transformer tap and note that as current flows through the hot gate winding it also flows through control windings number 1 and 3. But, also notice that these windings are wound in opposite directions which causes the magnetic poles to be opposite. This is the same as the control windings on the first-stage amplifiers.

Because current flow has been stopped in the first-stage cold gate winding, there will be very little, if any, current flow through control windings 2 and 4.

Fill in the blanks to complete the following statements.

1. For current to flow through the second-stage control windings, the magnetic poles of the first-stage control winding and the first stage gate winding must be _____(like/unlike).

2. Current flow through the second-stage control windings is _____(AC/DC).

3. The power source for the second-stage control windings is from the _____.

Answers to Frame 26: 1. unlike 2. DC 3. transformer

FRAME 27

Fold over sheet number 5. Notice that the second-stage bias windings have been added. Let's trace the current flow through this circuit. Starting at the negative (ground) point at the second-stage hot amplifier, current flows through the second-stage hot bias winding, through the second-stage cold bias winding, then through resistor R22 to point "C". From point "C" current flows over the same circuit as the first-stage bias windings to the 28V DC positive potential at the circuit breaker.

Current always flows through the bias windings in the same direction, so the magnetic poles will remain the same. Notice that all four bias windings have the same magnetic poles.

Fill in the blanks to complete the following statements.

1. The magnetic field of the bias windings opposes current flow through the gate windings because they have _____ (like/unlike) magnetic poles.

2. The windings that always have the same polarity are the _____ winding and the _____ winding.

Answers to Frame 27: 1. like 2. bias gate

FRAME 28

Fold over sheet number 6. This sheet adds the second-stage gate winding circuits. The power supply for the second-stage gate windings is from the transformer 12-volt taps. Notice that the second-stage gate winding voltage (12V) is greater than the first-stage gate winding voltage (3V). Recall from the basic amplifier, this is where the signal is amplified.

Current flows from the negative point at the 12-volt transformer tap to the second-stage hot gate winding. Because the second-stage hot control winding (number 1) is aiding the gate winding, we know current will flow through the gate winding. Current will also flow through the load, which isn't shown yet, and will return to the positive potential at the transformer. The diodes in this circuit will rectify the AC signal to a DC signal. Current is flowing through the gate winding, therefore, the poles can be determined. The magnetic poles of the control winding and the gate winding are opposite (unlike), so the control winding will be aiding the gate winding.

There was no current flow through the first-stage cold amplifier, so the second-stage control winding (coil number 4) will not have current flowing through it. Current is flowing through coil number 3 of the second-stage cold amplifier, but this causes the magnetic field from coil number 3 to oppose any current flow through the second-stage cold gate winding. This second set of controls windings acts as a positive shutoff for the amplifier that is not operating.

Fill in the blanks to complete the following statements.

1. The power supply for the second-stage gate windings is _____ volts.

2. The AC signal to the gate windings is rectified to a DC signal by the _____ in the circuit.

3. The second set of control windings in the second-stage amplifier act as a _____ _____ for the amplifier that is not operating.

Answers to Frame 28: 1. 12 2. diodes 3. positive shutoff

FRAME 29

Fold over sheet number 7. This adds the transistor circuit. The current flows from the negative point of the 12-volt transformer tap, through the second-stage hot gate winding and to the transistor circuit. Following current flow, notice that the signal will be applied to the emitter of each transistor and to the Zener diode (VR2). Remember from the basic magnetic amplifier that current flow from the gate winding normally flows through the resistor to the left of the Zener diode and back to the positive potential at the AC power source. Only when the signal becomes strong enough to break down the Zener diode, will current flow through it and cause the transistors to conduct.

As soon as current flows through the Zener diode to the positive potential, the base of the first transistor becomes more positive than the emitter. Now the first transistor will conduct. Ass soon as the current flows through the first transistor's emitter, the base of the second transistor becomes more positive than its emitter. Now the second transistor will conduct.

The hot signal from the bridge has now been used to make the "hot" transistors conduct. There was not current flow from the second-stage cold gate winding, so the transistors in the cold circuit will not conduct.

Fill in the blanks to complete the following statements.

1. The transistors will only conduct when the signal applied to their base is more _____than the signal applied to the _____.

2. The transistors are forward biased by the current flow from the second-stage _____windings.

3. The hot transistors will not conduct when the signal from the bridge has energized the first and second-stage _____amplifiers.

Answers to Frame 29: 1. positive emitter 2. gate 3. cold

FRAME 30

Fold over sheet number 8. So far we have taken a hot signal from the bridge and used it to cause current flow through the first-stage hot gate winding. This, in turn, cuased current to flow through the second-stage hot gate winding. The second stage provided current flow that caused the hot transistors to conduct. Sheet number 8 adds the bypass valve circuit (temperature control valve). This is the unit that we must control if we are to control the temperature from the air conditioning system. Remember, the transistors act like a switch or relay in this circuit. When the transistors are conducting, that's the same as closing the switch in a circuit.

Let's trace the current flow that operates the bypass valve. Starting at the turbine bypass valve ground, the current flows through the hot side of the valve motor and through the hot circuit to point "D". From point "D", current flows through both transistors (from the emitter to the collector), and to the 28V DC circuit breaker. The transistors have provided a complete circuit from the valve to the power source, so the valve will operate to the hot position.

Fill in the blanks to complete the following statements.

1. When the hot transistors are conducting, a circuit is completed to the hot side of the _____ _____ _____.

2. When a transistor is conducting, the current flows through it from its _____ to its _____.

Answers to Frame 30: 1. turbine bypass valve 2. emitter collector

FRAME 31

Fold over sheet number 9. We have seen how the hot signal from the bridge will run the bypass valve toward hot. But, with the circuit that we've traced, this hot signal could cause the valve to operate too far toward hot. This would cause the temperature to become too hot in the cockpit before the sensors could detect the temperature change and signal the valve to stop. This action would result in the bypass valve going first to hot then to cold and back to hot, always overshooting the exact position needed to deliver the selected temperature.

To prevent the valve from "hunting" or running continuously trying to maintain the temperature, a "feedback" circuit is used. The feedback circuit for both the hot and cold amplifiers are added to the diagram by sheet number 9.

The feedback circuit will cause the bypass valve to "pulse" instead of running coninuously. The pusling action prevents a rapid change in the valve position. It also prevents a rapid change in air temperature coming from the air conditioning system. The rate of the pusling action depends on the strength of the signal from the bridge. A real strong signal causes the valve to pulse at a rapid rate. A weaker signal causes the valve to pulse at a slower rate.

Fill in the blanks to complete the following statements.

1. The purpose of the feedback circuit is to prevent the valve from _____ the exact position needed to deliver the selected temperature.

2. The feedback circuit will cause the valve to _____instead of running _____.

3. The pulsing action of the valve prevents _____changes in air temperature.

Answers to Frame 31: 1. overshooting 2. pulse continuously 3. rapid

FRAME 32

Let's trace this feedback circuit to determine what controls the pusling action. Starting at the ground for the first-stage bias winding, point "A", follow the current from point "A" up through the first-stage hot bias winding. From the first stage hot bias winding, current can go in two directions. Current can go through resistor R14, to point "B" and back to the 28V DC source. The other path for current flow is through the feedback circuit. Current in the feedback circuit flows through resistors R24, R28, through the diode, then to point "D". From point "D" current flows through the transistors and up to the 28V DC circuit breaker. Now, notice that when the hot transistors start conducting they complete a path for current flow that operates the bypass valve and also a path for current from the first-stage hot bias winding. This provides a [illegible] path for current to flow from the first-stage hot bias winding and increases the amount of current that flows through the bias winding. What happens to the magnetic field around a coil when the current flow is increased? It increases. The strnegth of the magnetic field around a coil winding is in direct proportion to the current flow through the coil. Also keep in mind that the magnetic field of the bias winding is opposing current flow in the gate winding.

Fill in the blanks to complete the following statements.

1. When the transistors are conducting, they complete a path for current flow from the _____ _____ _____ and the _____ _____.

2. When the feedback circuit is in operation, current flow through the first-stage bias winding is _____.

3. When the current flow in the first-stage bias winding is increased, the magnetic field around this winding is _____.

4. The bias windings always oppose the _____ windings.

Answers to Frame 32: 1. turbine bypass valve feedback circuit
2. increased 3. increased 4. gate

FRAME 33

The increased current flow through the first-stage bias winding increases the opposition to current flow in the first-stage gate winding. This reduces or stops current flow in the gate winding, or, in other words, stops the first-stage magnetic amplifier from operating. By stopping the current flow in the first-stage gate winding, it also stops current flow in the second-stage control winding. This stops the operation of the second-stage amplifier which, in turn, removes the forward bias from the transistors, and they stop conducting. This, of course, stops the valve from operating and also stops current flow through the feedback circuit.

When current flow stops in the feedback circuit, there is no longer an increased opposition to current flow through the first-stage amplifier. This allows the signal to flow through the amplifier again, which allows the transistors to conduct. Of course the same sequence of events starts all over again. This causes the valve to pulsate until the temperature reaches a point to balance the bridge circuit.

We have taken a hot signal from the bridge and followed it through the complete automatic temperature control circuit. A signal for cold would operate the same as the hot signal, except we would have used the cold amplifiers, transistors, feedback circuit, and cold side of the valve.

NO RESPONSE

Technical Training

Aircraft Environmental Systems Mechanic

TRAINER AIRCRAFT AIR CONDITIONING

21 April 1971

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes ST PT 3ABR42231-PT-120, 4 December 1970.
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Designed For ATC Course Use

FOREWORD

This programmed text was prepared for use in the 3ABR42231 instructional system. The material contained herein has been validated using 30 students enrolled in the 3ABR42231 course. Ninety percent of the students taking this text surpassed the criterion called for in the approved lesson objectives. The average student required 3 hours and forty minutes to complete the text.

OBJECTIVES

After completion of this text, you will be able to:

1. State the source of air used for air conditioning an aircraft.

2. Identify each of the temperature control system components.

3. State the function of each component in a basic air conditioning system.

Standard of performance:

The student will demonstrate his knowledge of the objectives by answering 14 out of 20 questions.

INSTRUCTIONS

This programmed text presents information in small steps called "frames." After each frame you are asked to complete a statement or match some statements. Read the material presented and respond as directed. After you have made your response, compare your answer with the correct answer that is given on the page following each frame. If your response is incorrect, restudy the frame to get the information correct. Write the correct response next to your original response and then proceed to the next frame. If necessary, you may go back to check information previously discussed, but do not skip ahead.

INTRODUCTION

While working as an environmental system specialist you will be required to maintain air conditioning systems installed on various types of aircraft. This text describes the system used on a trainer type aircraft. It gives you the name and purpose of each component in this system including general operating characteristics about each component. It also shows you how the air is conditioned to maintain a comfortable environment for the flight crew.

In the next three frames of this text we will learn about the three different types of air used in an aircraft air conditioning system. They are; bleed air, conditioned air, and ram air. We will discuss each of these types of air individually. The illustration below shows a typical trainer aircraft air conditioning unit.

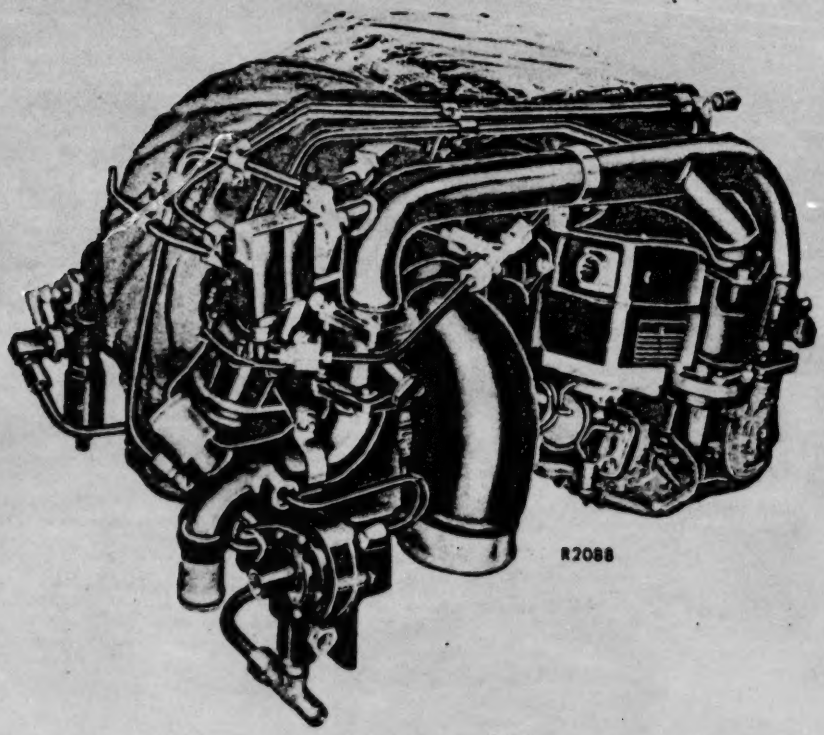


Figure 1.

NO RESPONSE IS REQUIRED.

Frame 2

To air condition an aircraft, we need a source of air. The primary source of air used for air conditioning is taken from the aircraft jet engine. It is taken from the last stage of compression. This is called engine bleed air . The engine bleed air has a high temperature and pressure. The actual temperature and pressure will vary for the different type aircraft, but usually will be around 900°F and near 200 psi. The bleed air is routed from the engine to the air conditioning unit through stainless steel ducting.

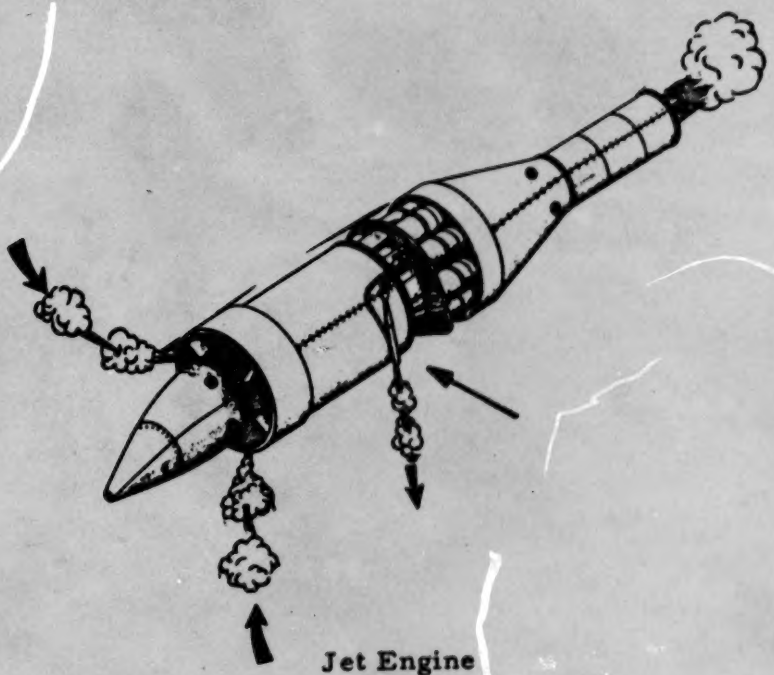


Figure 2.

Fill in the blanks to complete the following statements.

1. The primary source of air for air conditioning is the _____ _____.

2. The air tapped from the jet engine is called _____ _____ _____.

1175

Answers to frame 2: 1. jet engine 2. engine bleed air

Frame 3

The aircraft air conditioning system is designed to automatically maintain a comfortable temperature in the cockpit. Since an aircraft will encounter extreme temperatures, this system must be able to provide either hot or cold air. As you study this text, you will find that this system provides either hot air, cold air, or a mixture of hot and cold air. You will also find that this system removes the excess moisture from the air. From this we can define air conditioning as "controlling the temperature and humidity of the air."

Fill in the blanks to complete the following statements:

1. The aircraft air conditioning system is designed to provide either _____ or _____ air.

2. Air conditioning includes controlling the temperature and _____ of the air.

Answers to frame 3: 1. hot cold 2. humidity

Frame 4

Now let's discuss ram air. Ram air is air which is moving simply because of the motion of an object passing through the air.

As an example, you are driving your car at 60 mph. Your window is open and you stick your left hand out to make a left turn signal. It feels like there is a strong wind blowing on your hand. This wind is what we call ram air. As you slow down and stop, the wind also stops. Again you proceed at 60 mph. You feel the need to ventilate your car. You have no air conditioner in your car. You reach down and pull the vent knob out and immediately you feel the cool air coming in through the vents. This ram air is now ventilating your car.

Fill in the blank to complete the following statement.

1. The air felt on your face as you run would be called _____ _____.

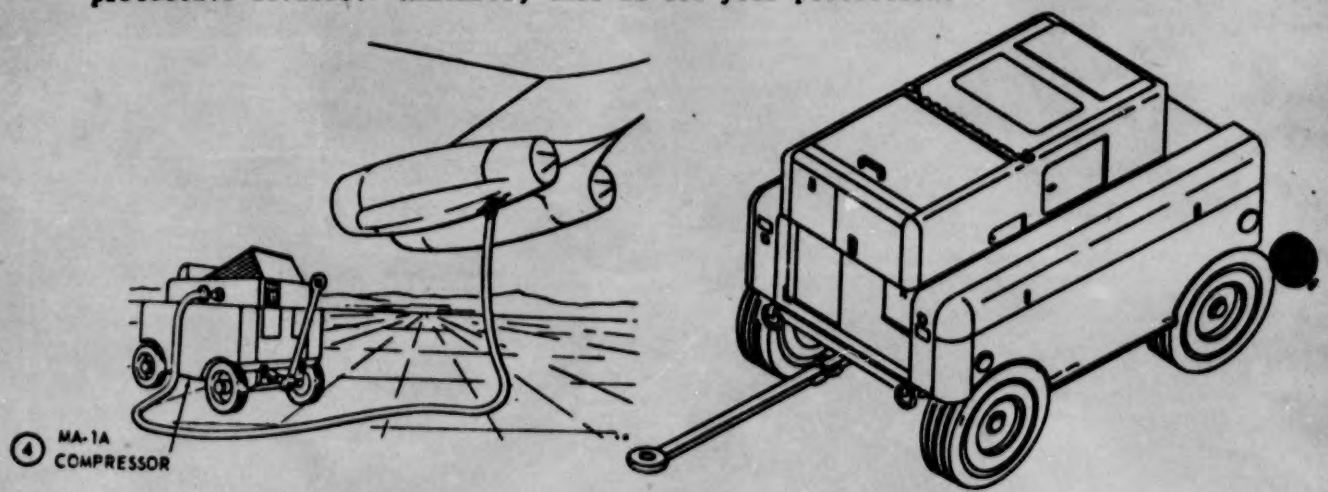
1177

Answer to frame 4: 1. ram air

Frame 5

During maintenance it is often necessary to operate the air conditioning system on the ground. The air for operating the system can be obtained by operating the aircraft engine or by using a ground air cart. The ground air cart is cheaper and safer to operate and is usually used. An MA-1A ground air cart or compressor is shown both idle and in use. This unit contains a small jet engine and supplies air in much the same manner as the aircraft engine. However, there is one major difference. The air supplied by the ground air cart will deliver a much lower pressure and temperature. The ground air cart is also used to start the aircraft engine, since many jet engines use air driven starters.

You should recall from previous lessons on safety that anytime you are near an operating jet engine you must wear protective devices to prevent damage to your ears. This precaution also applies to the ground air cart. Any time you are working near or operating an MA-1A cart you must wear ear protective devices. Remember, this is for your protection.



MA-1A Compressor MA-1A Ground Air Cart

Figure 3.

Fill in the blanks to complete the following statements.

1. The ground air cart can be used to supply air for _____ the aircraft engines.

2. The ground air cart supplies a source of air for ground checking the _____ _____ _____.

3. When operating an MA-1A cart you must wear ear _____ _____.

Answers to frame 5: 1. starting 2. air conditioning system

3. protective devices

Frame 6

The bleed air used for air conditioning can be supplied from one or more engines. The illustration at the right shows bleed air being supplied by two engines. Check valves are used at each engine bleed air tap-off to prevent a reverse flow of air. If engine Number 1 were shut down for some reason, the check valve on engine Number 1 would close, preventing air from engine Number 2 from flowing into the compressor section of engine Number 1.

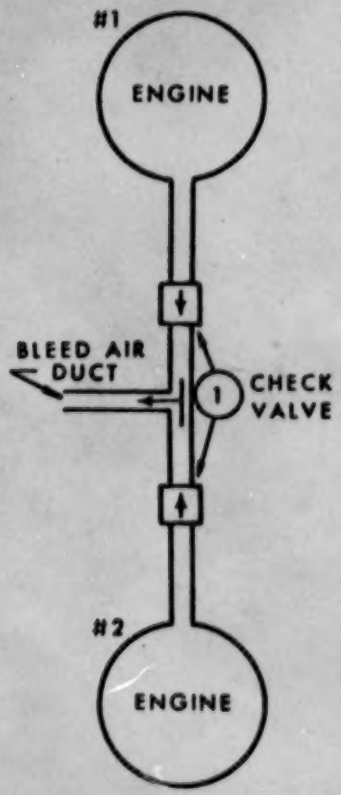


Figure 4.

Fill in the blanks to complete the following statements.

1. A check valve is installed at each _____ _____ _____ tap-off.

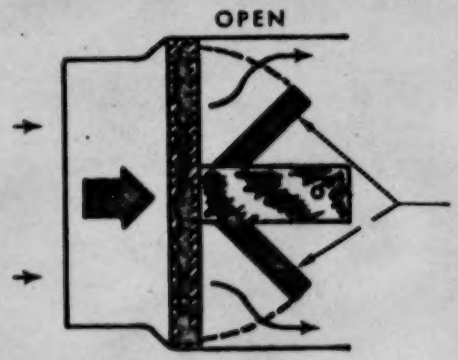
2. With engine Number 1 operating, and engine Number 2 shut down, the _____ _____ would prevent engine bleed air from flowing into engine Number 2.

1179

Answers to frame 6: 1. engine bleed air 2. check valve

Frame 7

A check valve, as shown in the illustration, is used to allow airflow in one direction only. The direction of airflow is indicated by the direction of the arrow stamped on the valve body. A check valve consists of two flapper type valves. When air flows in the direction of the arrow it will push the flapper valves open, but if it tries to flow in the reverse direction air pressure will push the flapper valves closed.



CLOSED

Figure 5.

Fill in the blanks to complete the following statements.

1. Check valves allow airflow in _____ _____ _____.

2. The purpose of the check valve is to prevent _____ _____.

3. The valve is actuated closed by _____ _____.

1202

Answers to frame 7: 1. one direction only 2. reverse airflow

3. air pressure

Frame 8

Match the items in column B with the correct statement in column A.

	COLUMN A		COLUMN B
_____1.	The primary source of air for air conditioning a jet type aircraft.	a.	Ground air cart
		b.	Air conditioning system
_____2.	Used to start engines and ground check the air conditioning system.	c.	Jet engine
		d.	Check valve
_____3.	Prevents a reverse airflow at the engine bleed air tap-offs.	e.	Flow control valve
_____4.	Maintains a comfortable cockpit temperature.		

1181
Answers to frame 8: 1. c 2. a 3. d 4. b

Frame 9

The air from the engine is routed through a system shutoff valve and then to the air conditioning package. The air conditioning package, shown below, is designed to cool the hot engine bleed air coming from the jet engine. It also mixes hot and cold air to maintain a desired temperature in the cockpit. This mixture of air is routed to the cockpit through the use of ducting. The major components of the air conditioning package are the heat exchanger, cooling turbine, temperature control valve, and water separator anti-ice control system.

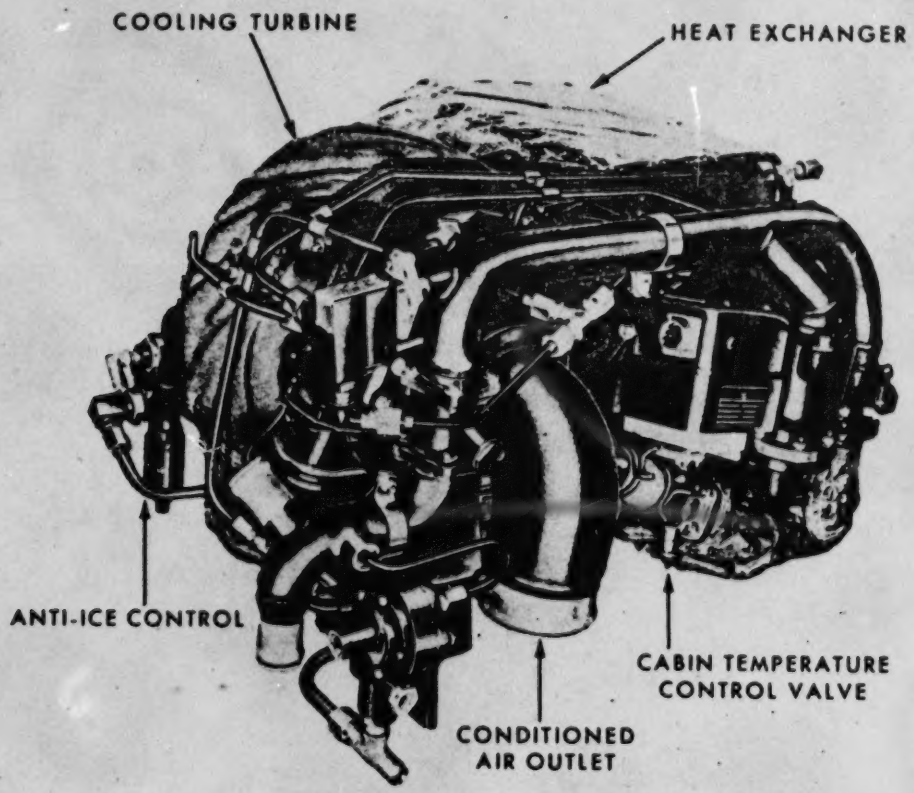


Figure 6.

Fill in the blanks to complete the following statements.

1. One purpose of the air conditioning package is to _____ the engine-_____ air.

2. The air conditioning package provides air to the cockpit at the desired temperature by mixing _____ and _____ air.

Answers to frame 9: 1. cool, bleed 2. hot, cold

Frame 10

For the remainder of this lesson, use the foldout that is located in the back of this text. Fold out this diagram now.

This foldout is an airflow diagram of the air conditioning system. Use it as a reference for component location within the system. As each component is discussed, refer to this diagram. Most frames will also have an illustration of the component. The shaded area on the schematic shows engine bleed air and conditioned air flowing to the cockpit.

The bleed air taken from the engines first passes through the check valve, item 1, which we discussed in frames 6 and 7.

NO RESPONSE REQUIRED.

The air conditioning system shutoff valve is shown as item 2, in the foldout and in the illustration in this frame. It controls the bleed air going to the air conditioning system. When the valve is closed there is no airflow through the system. When the valve is open, air will flow through the air conditioning system to the cockpit. The system shutoff valve, illustrated at the right, is a sliding gate type valve which is actuated by a 115-volt AC motor. It is controlled by the master switch, item 17. When this switch is placed in the CABIN PRESS position the system shutoff valve will open. Placing the master switch in the RAM DUMP position will close the system shutoff valve. This valve is located between the air conditioning package and the aircraft engine.

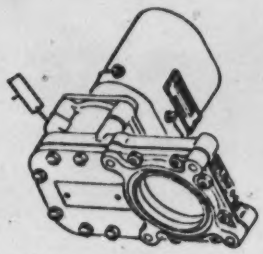


Figure 7. System Shutoff Valve.

Fill in the blanks to complete the following statements.

1. The unit used to control the air going to the air conditioning package is the _____ _____ _____.

2. When the master switch is in the CABIN PRESS position, the system shutoff valve will _____.

3. The system shutoff valve is _____ actuated.

Answers to frame 11: 1. system shutoff valve 2. open 3. motor or electrically

Frame 12

The heat exchanger is shown as item 3 in the foldout and within this frame. It is used to partially cool the engine bleed air with ram air. Ram air is obtained from a ram air scoop that extends out into the air stream. Its impact pressure drives the cooling ambient air through the heat exchanger. A cutaway view of a typical heat exchanger is shown at the right. It consists of many small tubes through which the bleed air passes. Ram air is circulated over and around the tubes of the heat exchanger and cools the bleed air. This is called an air to air heat exchanger. The heat from the bleed air is transferred to the ram air. This heated ram air is exhausted overboard. This is the first stage of cooling within the air conditioning package.

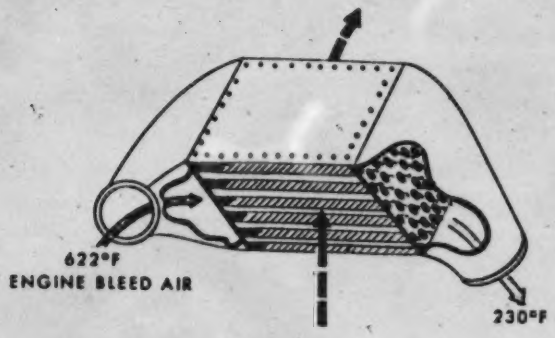


Figure 8.

Fill in the blanks to complete the following statements.

1. The purpose of the heat exchanger is to partially cool the _____ _____ _____.

2. The heat exchanger cools the bleed air by transferring heat to the _____ _____.

3. The heat exchanger is the _____ stage of cooling.

1185

Answers to frame 12: 1. engine bleed air 2. ram air 3. first

Frame 13

We can easily compare the operation of a heat exchanger to that of a car radiator. The hot water coming from the engine passes inside of a car radiator. The radiator must cool the water and send it back to the engine to cool it as the car travels. The heat from the hot water in the radiator is carried away by the ram air flowing across the core of the radiator. This action cools the hot water. We would call this radiator a "water to air" type heat exchanger.

Fill in the blanks to complete the following statements.

1. The car radiator is compared to the aircraft _____ _____.

2. In the radiator, the hot water is like the _____ _____ in a heat exchanger.

1208

Answers to frame 13: 1. heat exchanger 2. bleed air

Frame 14

On some heat exchangers the bleed air will pass through only once. On other types, the bleed air may pass through two or more times. On the trainer aircraft, the bleed air passes through the heat exchanger four times, as shown in the illustration at the right and as item 3 in the foldout.

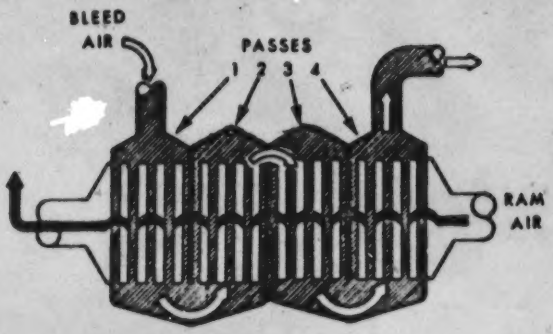


Figure 9.

Fill in the blanks to complete the following statements.

1. The heat exchanger used on the trainer type aircraft is a _____ pass heat exchanger.

2. A double pass heat exchanger would allow the _____ _____ to pass through it two times.

1187
Answers to frame 14: 1. four 2. bleed air

Frame 15

The partially cooled bleed air from the heat exchanger is routed to the turbine fan assembly, items 4 and 5. The turbine fan assembly consists of a turbine and fan mounted on a common shaft as shown in illustration "A." The bleed air goes in the turbine inlet, illustration B, where it is directed through several small nozzles onto the turbine wheel. The pressure of the air causes the turbine to rotate at a very high speed. (Depending on the type of turbine, speeds can go as high as 60 to 70,000 rpm.) The air is expanded rapidly as it passes through the turbine assembly. This rapid expansion of the air drops the temperature. The cold air then comes out at the turbine outlet into a duct leading to the cockpit. This cooling process can be compared to the effect noted when releasing air from an inflated tire. As you may recall, this air usually feels cool. This is also due to rapid expansion.

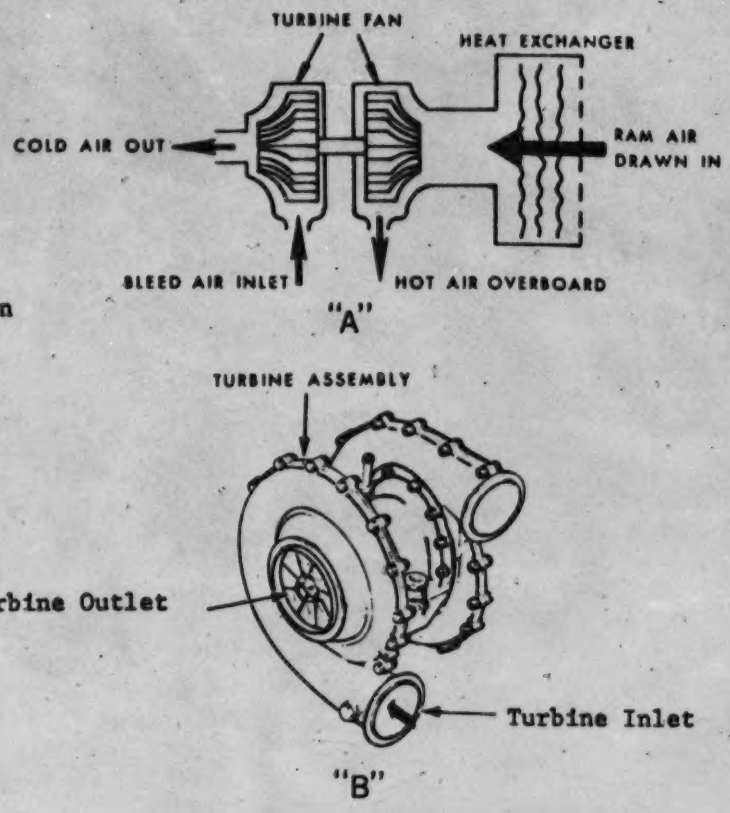


Figure 10.

The turbine fan assembly is the second and final stage of cooling in the air conditioning package.

Fill in the blanks to complete the following statements.

1. The turbine cools the air by _____ _____.
2. The turbine is rotated by _____ _____.
3. The turbine fan assembly is the _____ stage of cooling.

Answers to frame 15: 1. rapid expansion 2. air pressure 3. second or final

Frame 16

We have stated that the turbine and fan are connected by a common shaft. This is shown in the illustration in Figure 11. As the turbine turns, it also turns the fan. One purpose of the fan assembly is to pull ram air across the heat exchanger. Ram air comes in through the ram air inlet, item 6, and is exhausted overboard through the ram air outlet, item 7.

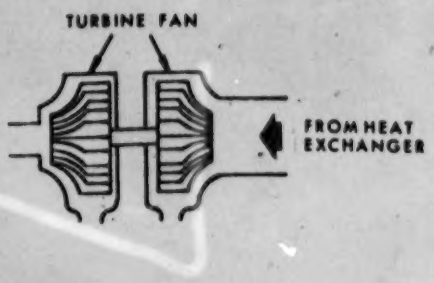


Figure 11.

Remember, during ground operation the aircraft is not moving, so there is no ram air for cooling in the heat exchanger. The fan, which is being driven by the turbine, draws cooling outside air through the heat exchanger. This air, then, cools the bleed air and increases the cooling efficiency of the turbine.

Fill in the blanks to complete the following statements.

1. One purpose of the fan is to pull _____ _____ across the heat exchanger.

2. The cooling efficiency of the heat exchanger is increased by the action of the _____.

3. The fan is driven by the _____.

1189

Answers to frame 16: 1. ram air 2. fan 3. turbine

Frame 17

Another purpose of the fan is to put an air load on the turbine. The turbine must work against this air load. By making the turbine work against this load, the turbine speed is held down. This is another purpose of the fan, to keep the turbine from overspeeding.

The fan, by air-loading the turbine, causes the turbine to work harder. The harder the turbine works the colder the turbine outlet air temperature becomes. Here is why the temperature drops. Heat energy is in the bleed air. This heat energy is the energy used to spin the turbine. As the turbine spins, the heat energy is used up. When the heat is removed, the result, an absence of heat, is cold.

Scientifically speaking, the turbine changes heat energy into mechanical energy which is transmitted to the fan by their common shaft. The fan, then, converts the mechanical energy back into heat energy which goes overboard with the ram air. The air comes off the fan much hotter than when it was drawn into the fan.

To summarize, the two purposes of the fan are:

1. Puts a workload on the turbine.

2. Prevents the turbine from overspeeding.

Fill in the blanks to complete the following statements.

1. Overspeeding of the turbine is prevented by the _____.

2. Much of the heat taken from the engine bleed air goes overboard in the _____ _____.

Answers to frame 17: 1. fan 2. ram air

Frame 18

Match the unit in column B with the purpose given in column A.

	COLUMN A	COLUMN B
_____1.	Stops and starts the flow of air to the air conditioning package.	a. Turbine Fan Assembly
_____2.	Partially cools the bleed air by transferring heat to the ram air.	b. Heat Exchanger
_____3.	Draws ram air across the heat exchanger.	c. Air Conditioning System
_____4.	Drives the fan and causes the air to be rapidly expanded.	d. Shutoff Valve
_____5.	Prevents the turbine from overspeeding.	e. Turbine
_____6.	Puts a workload on the turbine.	f. Fan
_____7.	Is comparable to a car radiator.	

1191

Answers to frame 18: 1. d 2. b 3. f 4. e 5. f 6. f 7. b

Frame 19

So far, we have followed the air from the engines, (review this by studying illustration A below) through the air conditioning system shutoff valve, then through the heat exchanger and turbine fan assembly. This provided the cold air needed for cooling. This cold air could be below 0°F so we must supply some hot air to mix with this cold air. We can then supply comfortable temperature air to the cabin. Locate the cabin temperature control valve illustrated in A and B below and in the foldout (item 8). If we open the temperature control valve, air will come directly from the bleed air source to the cabin. Under this condition, the temperature in the cockpit would quickly get very hot. If we close the valve, all the air will be forced through the cooling units, (heat exchanger and turbine). Now the cockpit receives only cold air. By controlling the opening and closing of this valve, we can control or modulate the temperature of the air going to the cockpit. Remember, for hot air the valve opens and for cold air the valve will close. To get warm air, the valve moves to an approximate mid-position.

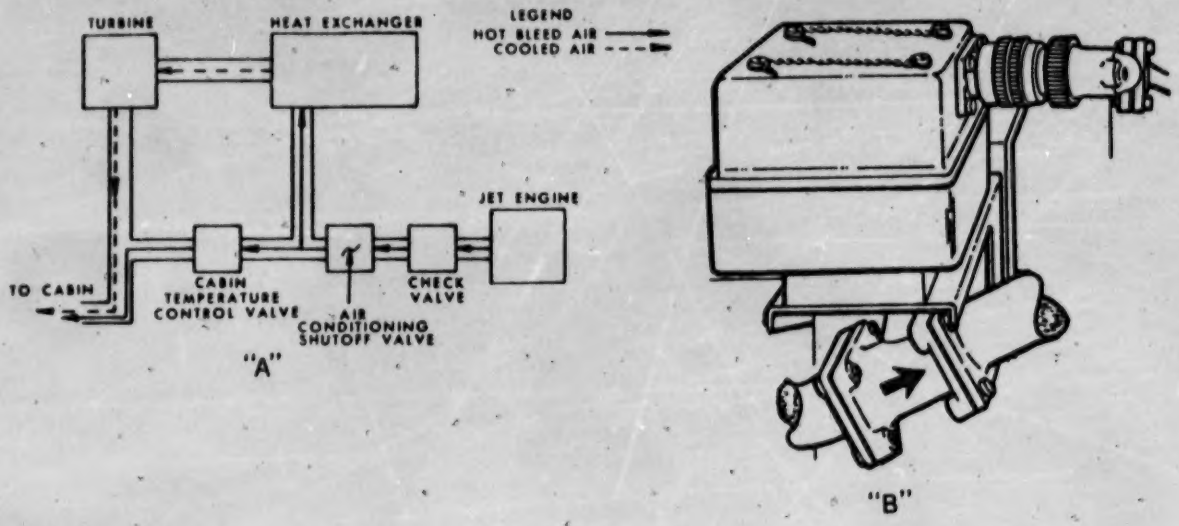


Figure 12.

The cabin temperature control valve is shown in illustration B. It is an electric motor actuated, butterfly type valve. The motor is operated to position the valve.

Fill in the blanks to complete the following statements.

1. If the temperature control valve is full open, the temperature of the air entering the cockpit will be _____.

2. When cold air is desired in the cockpit, the temperature control valve is _____.

3. The temperature control valve is actuated by an _____ _____.

Answers to frame 19: 1. hot 2. closed 3. electric motor

Frame 20

A few lessons earlier we mentioned that moisture is present in the air. This is called humidity. The removal of this moisture is an important part of air conditioning. When air is cooled by the turbine, this moisture condenses. The outlet temperature of the turbine can drop below freezing, thereby causing fog or snow to enter the cabin from the air conditioning outlets. Ambient air at lower altitudes (10,000 feet and below) contains much more moisture than does the air at higher altitudes. To remove this undesirable moisture from the conditioned air, a water separator is installed in the system. It is shown below and is item 9 on the foldout.

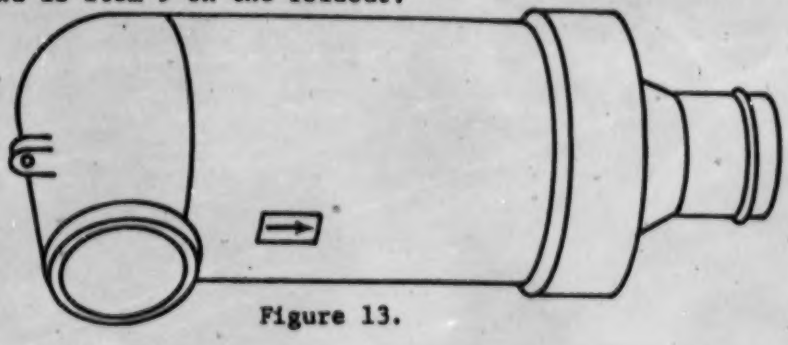


Figure 13.

Fill in the blanks to complete the following statements.

1. The moisture condensed in the air as a result of refrigeration is removed by the _____ _____.

2. Should the pilot report a fogging condition in the cockpit, it would indicate a malfunctioning _____ _____.

1193
Answers to frame 20: 1. water separator 2. water separator

Frame 21

The water separator illustrated below contains a condenser assembly which consists of a louvered cone and a fiberglass blanket (condenser bag), The cooled moist air enters the air inlet and passes over the fiberglass blanket where the moisture is condensed into water droplets. The louvered cone is designed to cause the air to swirl as it passes through it. This motion throws the water droplets against the water separator housing. The droplets collect on the housing and drain down to the moisture drain where it is passed overboard. The conditioned air, with the excess moisture removed, flows on into the cockpit.

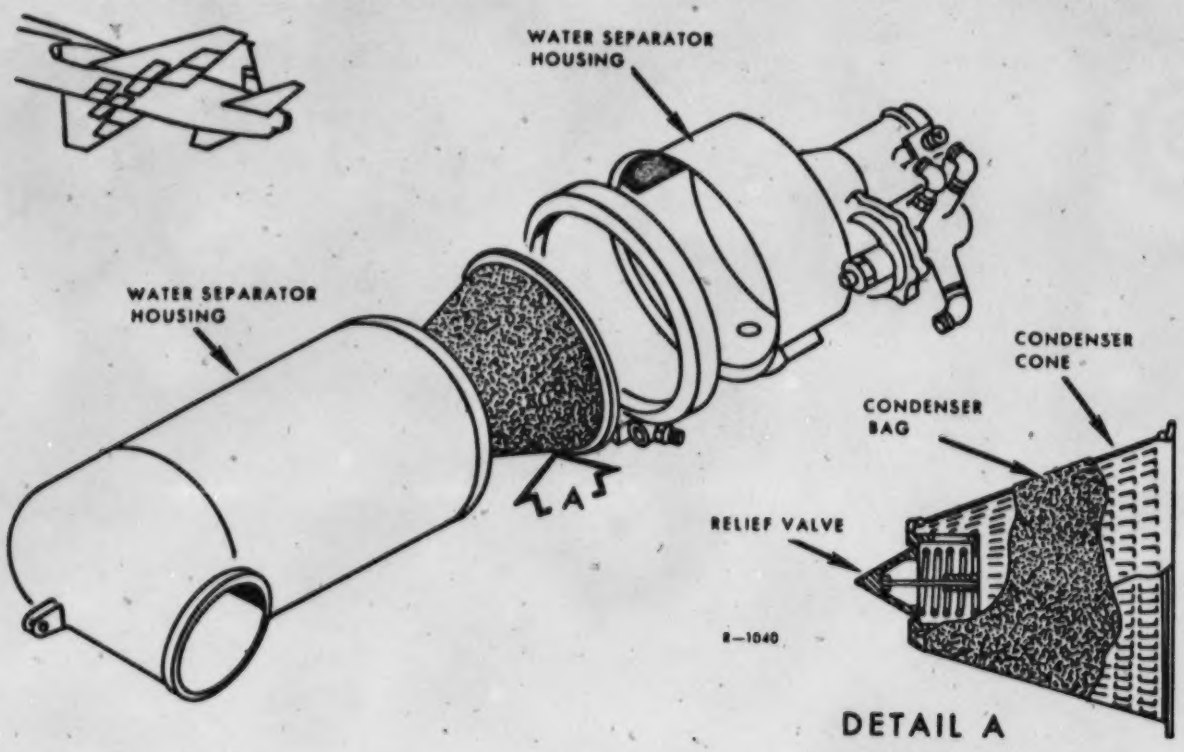


Figure 14.

Fill in the blanks to complete the following statements.

1. The excess moisture is condensed into water droplets by the _____ _____.

2. The water droplets are directed against the water separator housing by the _____ _____.

3. The purpose of the water separator is to _____ _____ _____.

Answers to frame 21: 1. fiberglass blanket 2. louvered cone

3. remove excess moisture

Frame 22

The refrigeration package has the ability to reduce the air temperature to below freezing. This could cause icing in the water separator. Should a layer of ice form on the condenser bag, (sometimes called the blanket) it will restrict the airflow to the cabin. A pressure relief valve is installed to allow the air to bypass (go around) the water separator condenser assembly should the blanket become clogged with ice, dirt, or any other substance. This valve is attached to the cone assembly as illustrated below. The pressure relief valve is held closed by spring pressure. If the blanket becomes clogged, the pressure of the air will overcome the spring pressure and force the relief valve open. With this valve open, moist air is allowed to pass on through the water separator because moisture laden air is certainly better than no air at all!

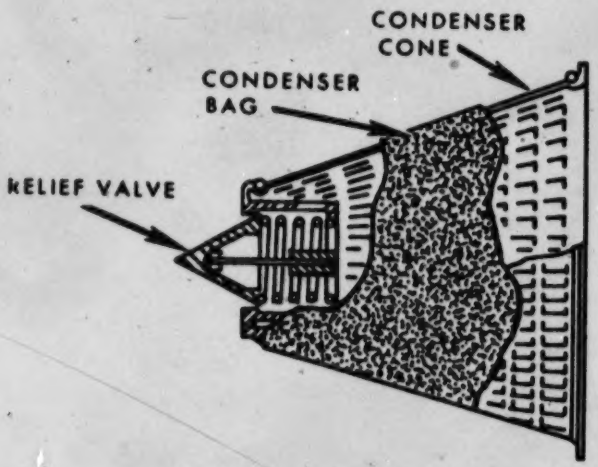


Figure 15.

Fill in the blanks to complete the following statements.

1. The unit which allows air to bypass the water separator is the _____ _____ _____.

2. The pressure relief is opened by _____ _____.

3. If the blanket froze over, the pressure relief valve would open and could cause _____ in the cockpit.

Answers to frame 22: 1. pressure relief valve 2. air pressure

3. fogging

Frame 23

In the previous frame we mentioned that the water separator blanket could freeze over. To prevent this, an anti-icing system is built into the air conditioning system. This system consists of an anti-ice controller, item 10, and an anti-ice valve, item 11 on the foldout. Should ice start to form on the water separator blanket, this system will cause the air tempe to increase and melt the ice.

This system is operated by air pressure only. Should the water separat start to freeze, a difference in air pressure will be sensed by the anti-ice controller. This difference in pressure will be sensed between the wate separator inlet, point B on the foldout, and the separator outlet, point C. The difference in pressure between these two points will signal the anti ice controller, which in turn, signals the anti-ice valve. This system melt the ice after it starts to form rather than preventing ice from forming. Other systems that we will study later are designed to prevent ice from form

Fill in the blanks to complete the following statements.

1. The anti-ice system consists of an anti-ice _____ and an anti ice _____.

2. Icing of the water separator is sensed by a difference in _____ between the water separator _____ and _____.

Answers to frame 23: 1. controller, valve 2. pressure, inlet, outlet

Frame 24

The anti-ice valve, shown at the right, opens to allow partially cooled air to bypass the cooling turbine and mix with the air entering the water separator. This air has been partially cooled by the heat exchanger, but is still warm enough to raise the temperature of the air entering the water separator. This will melt any ice that has formed on the blanket. This valve is actuated open by air pressure from the anti-ice controller and is spring loaded closed.

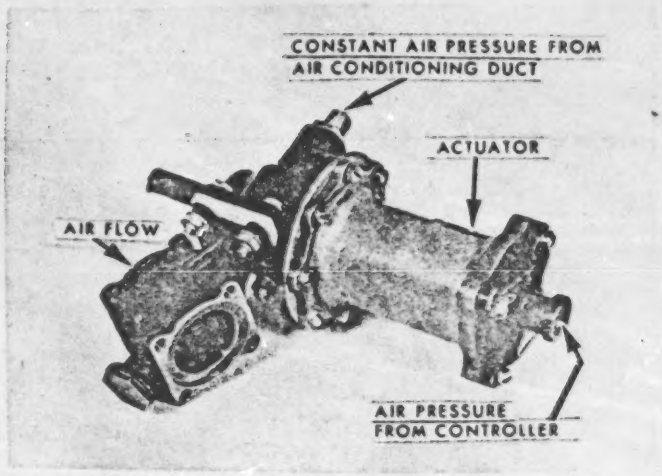


Figure 16.

Fill in the blanks to complete the following statements.

1. The unit that opens to allow warm air to enter the water separator for anti-icing of the blanket is the _____ _____.

2. When an icing condition exists, air pressure will _____ the anti-ice valve.

3. The air conditioning pack anti-ice system removes ice from the water separator by _____ the air temperature entering the _____ _____

1197

Answers to frame 24: 1. anti-ice valve 2. open 3. increasing, water separator

Frame 25

The opening and closing of the anti-ice valve is controlled by the anti-ice controller illustrated at the right. The anti-ice controller senses the pressure at the water separator inlet, point B on foldout 1, and the water separator outlet, point C, by means of sensing lines. A difference in pressure between the inlet and outlet causes a diaphragm in the controller to move. This opens a port that directs air pressure to open the anti-ice valve. The anti-ice controller senses an icing condition and controls the position of the anti-ice valve.

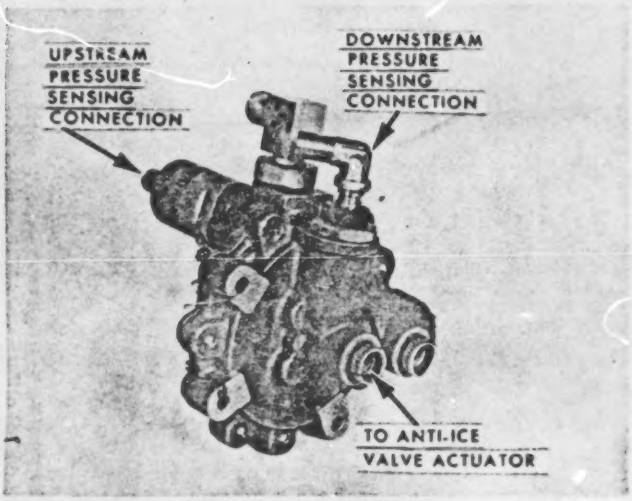


Figure 17.

Fill in the blanks to complete the following statements.

1. Icing of the water separator blanket will cause a difference in _____ across the water separator.

2. The position of the anti-ice valve is controlled by the _____ _____.

3. The anti-ice _____ and the anti-ice _____ work together to remove ice from the water separator.

1220

Answers to frame 25: 1. pressure 2. anti-ice controller 3. valve, controller

Frame 26

Match the units in column B with the purpose of the unit given in column A.

COLUMN A	COLUMN B
_____1. Removes moisture from the conditioned air.	a. Temperature control valve
_____2. Opens to allow warm air to mix with cold air to melt any ice that has formed on the water separator.	b. Water separator pressure relief valve
_____3. Used to control the temperature of the air entering the cockpit.	c. Water separator
_____4. Senses a difference in pressure between the inlet and outlet of the water separator.	d. Anti-ice controller
_____5. Allows air to bypass the water separator if the blanket becomes clogged.	e. Anti-ice valve
	f. System shutoff valve

1199

Answers to frame 26: 1. c 2. e 3. a 4. d 5. b

Frame 27

In frame 19 we discussed how the air is conditioned by cooling the bleed air and removing the excess moisture. We also discussed the temperature of the air, and, in frame 19, how it is controlled by positioning the temperature control valve. However, we cannot spare a crew member to continually manipulate the temperature control valve to maintain a comfortable cabin temperature. This brings in a need for an automatic temperature controller. We now have a temperature control system which will regulate the temperature in the cockpit automatically or allow the pilot to control the system manually. A schematic of the temperature control system is illustrated at the right. It consists of the following components.

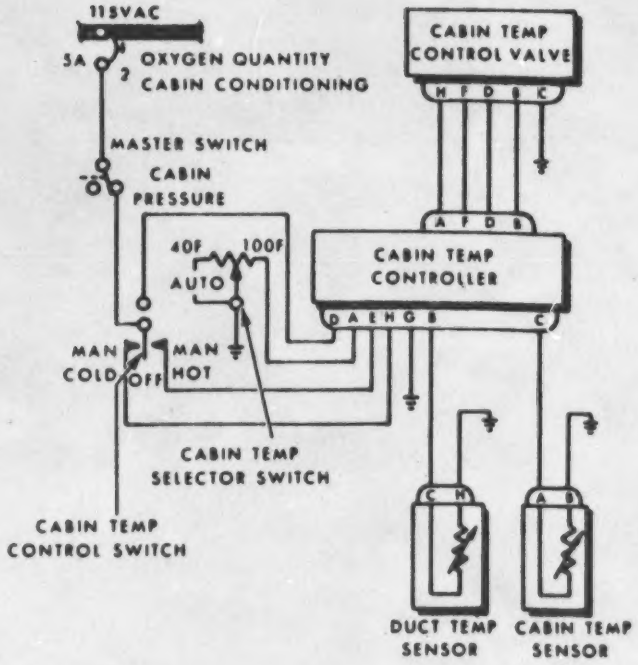


Figure 18.

a. Cabin temperature control switch.

b. Cabin temperature selector.

c. Cabin temperature sensor.

d. Duct temperature sensor.

e. Cabin temperature controller.

f. Cabin temperature control valve.

Each of these components will be discussed in detail in the following frames.

NO RESPONSE REQUIRED.

1200

Frame 28

The cabin temperature control switch, shown in the illustration at the right and as item 12 on the foldout, is used to provide automatic and manual temperature selection. This switch has four positions, AUTOMATIC, MANUAL COLD, MANUAL HOT, and OFF. When placed in the AUTO position, 115 volts AC is applied to the cabin temperature controller. This will cause the temperature to be controlled automatically. When this switch is placed in either MAN COLD or MAN HOT the pilot directly controls operation of the temperature control valve (item 8 on the foldout). The switch is spring loaded to the OFF position when using MAN HOT and MAN COLD. This means that the switch will not stay in these positions, but must be held there. In manual operation, if the pilot desires warmer air, he can hold the switch in MAN HOT which will cause the valve to operate toward the open position as long as the switch is held, but to stop when the switch is released. If colder air is desired he can hold the switch in MAN COLD and the valve will travel toward the closed position.

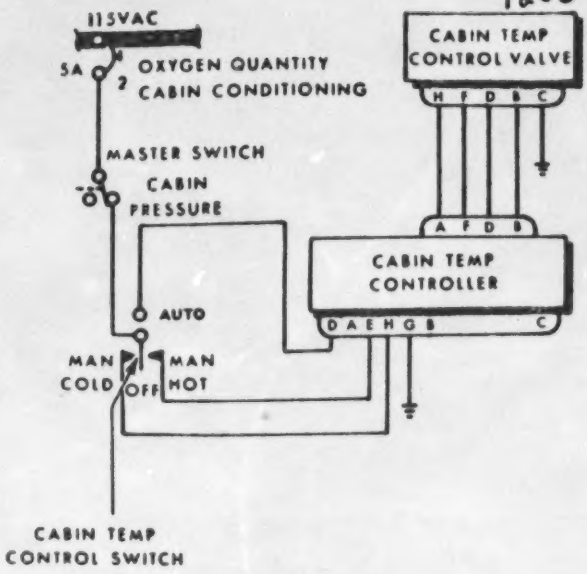


Figure 19.

Fill in the blanks to complete the following statements.

1. The switch used to manually control the cockpit temperature is the cabin _____ _____ _____.

2. Holding the cabin temperature control switch in MAN COLD will cause the temperature control valve to _____ (open/close).

3. When the cabin temperature control switch is placed in AUTO, it directs 115 volts AC to the cabin _____ _____.

1223

1201

Answers to frame 28: 1. temperature control switch 2. close 3. temperature controller

Frame 29

The cabin temperature selector, shown in the illustration at the right and as (item 13 on the foldout, is used to select the desired temperature during automatic operation. This selector is a rheostat and forms part of a temperature control bridge circuit. It allows the pilot to select the temperature he wants to maintain. The rheostat will control the temperature control valve only if the temperature selector switch is in the automatic position. The cabin temperature selector and the cabin temperature control switch are both located on a panel in the cockpit.

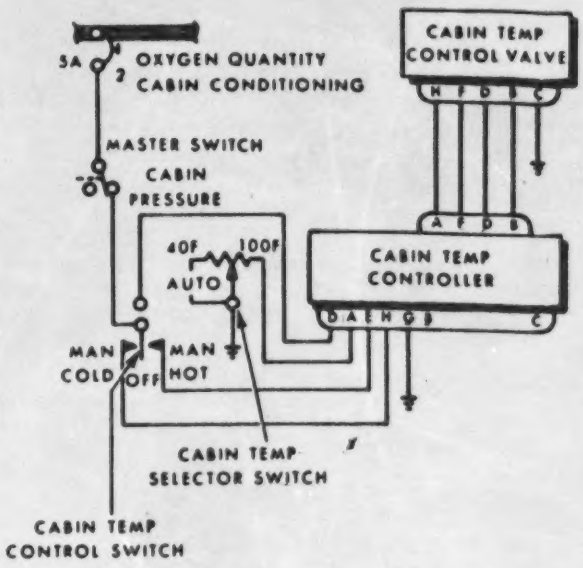


Figure 20.

Fill in the blanks to complete the following statements.

1. When the temperature control switch is placed in AUTO, the desired cockpittemperature is selected by rotating the _____ _____ _____.

2. The cabin temperature selector is part of the temperature control _____ circuit.

3. The cabin temperature selector is a _____.

1224

Answers to frame 29: 1. cabin temperature selector 2. bridge 3. rheostat

Frame 30

The cabin temperature sensor, shown in the illustration at the right and as (item 14 on the foldout, senses the cockpit air temperature. This sensor is also part of the temperature control bridge. Its purpose is to sense the temperature in the cockpit and send this signal to the controller in the form of a resistance signal. Here is how it is done. The sensor contains a resistance element which changes resistance with changes in temperature. This resistance element forms one leg of the bridge circuit of the cabin temperature controller. This sensing element has a negative coefficient of resistance. This means that as air temperature around the sensor goes up, the resistance value of the sensor goes down, and as the temperature around the sensor goes down, the resistance value of the sensor goes up.

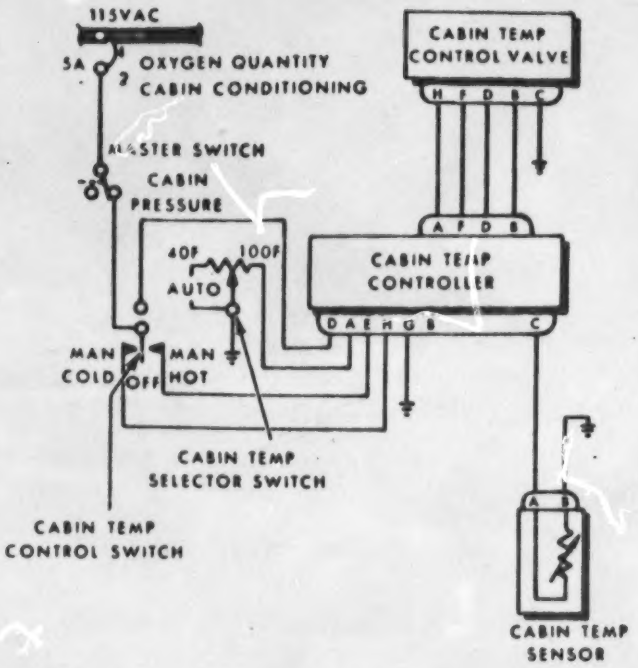


Figure 21.

Fill in the blanks to complete the following statements.

1. As the temperature around the sensor goes up, the resistance of the sensor goes _____.

2. The cabin sensor sends signals to the _____ _____ _____.

3. An open in the sensor will mean a _____ (high/low) resistance.

4. An increase in temperature around the sensor will cause the resistance of the sensor to _____ (increase/decrease).

1203

Answers to frame 30: 1. down 2. cabin temperature controller
3. high 4. decrease

Frame 31

The duct temperature sensor, shown in the illustration at the right and as (item 15 on the foldout, senses the temperature of the conditioned air in the air supply duct before it passes through the water separator. The resistance of the sensor changes with changes in air temperature and also causes a signal to be sent to the cabin temperature controller. This sensing element also has a negative coefficient of resistance and forms a part of the temperature control bridge circuit.

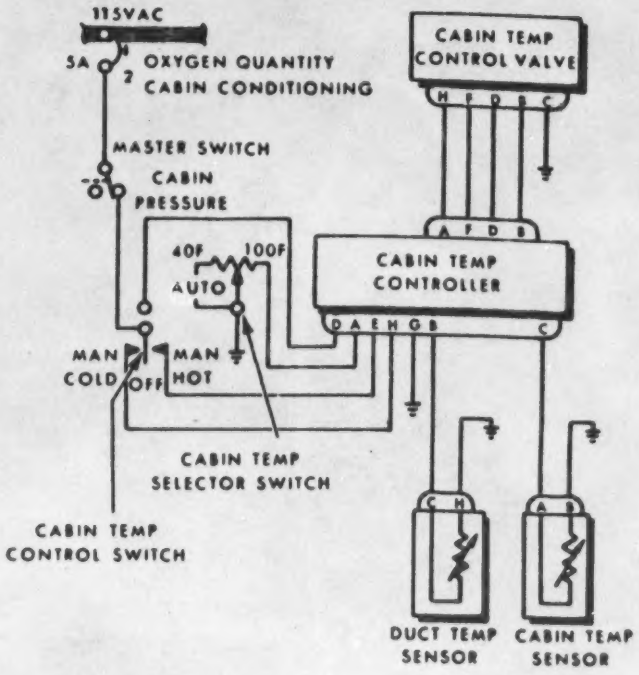


Figure 22.

The purpose of the duct temperature sensor is to sense major changes in the air temperature before it enters the cockpit. In doing so, it prevents extreme temperature changes from occurring in the cockpit. This allows the cabin temperature sensor to accurately maintain the selected temperature.

Fill in the blanks to complete the following statements.

1. The cabin and duct sensors both have _____ coefficients of resistance.

2. A change in cabin temperature is sensed by the _____ _____ _____.

3. An increase in duct temperature will cause the sensor resistance to _____ (increase/decrease).

4. The temperature selector switch, cabin sensor, and duct sensor each form a part of the temperature control _____ _____.

1226

Answers to frame 31: 1. negative 2. cabin temperature sensor
3. decrease 4. bridge circuit

Frame 32

Remember that the temperature selector, cabin temperature sensor, and duct temperature sensor each form part of the bridge circuit. This part of the bridge circuit then sends signals to the temperature controller. The cabin temperature controller is the brains of the system. Look at the diagram on the right. Notice that the wiring from both sensors connects to the controller. Also notice that the wiring from the cabin temperature control valve is also connected to the controller. Placing the cabin temperature control switch in AUTO will send 115 volts AC to the controller. The controller receives signals from the temperature selector rheostat, duct sensor, and cabin sensor. Based on these input signals, the controller directs electrical power out to the temperature control valve. The electric motor will move the temperature control valve to the required position and maintain the temperature selected by the pilot.

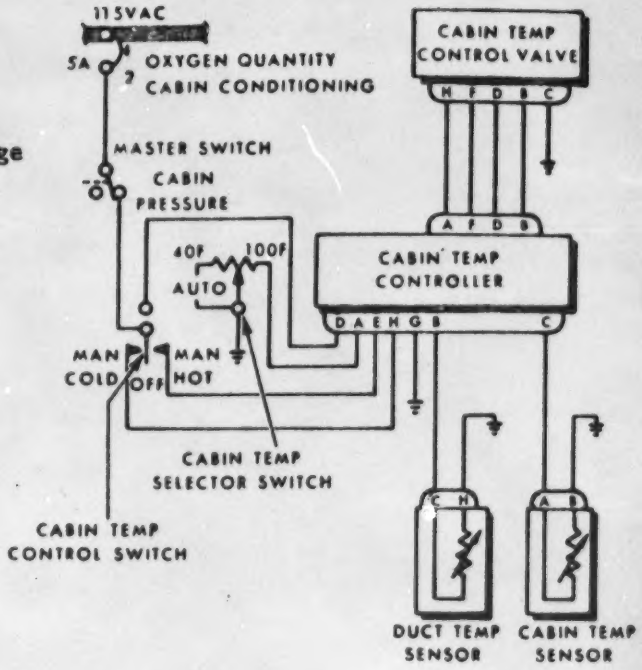


Figure 23.

Fill in the blanks to complete the following statements.

1. The unit which automatically controls the temperature in the cockpit is the _____ _____ _____.

2. The cabin temperature controller receives signals from the cabin temperature _____, _____ sensor, and the _____ sensor.

3. The cabin temperature controller directs electrical power to control the position of the _____ _____ _____ _____.

4. If the resistance of the duct temperature sensor increases, the temperature controller will receive a _____ (cold/hot) signal.

1205

Answers to frame 32: 1. cabin temperature controller 2. selector, cabin, duct 3. cabin temperature control valve 4. hot

Frame 33

Match the units in column B with the purpose of the unit given in column A.

	COLUMN A	COLUMN B
_____1.	Senses temperature of the air in the cabin air supply before it enters the cabin.	a. Cabin temperature controller
_____2.	Senses temperature of the air in the cabin.	b. Temperature selector
_____3.	Allows the pilot to select the temperature he wants to maintain.	c. Temperature control valve
_____4.	Receives signals from the sensors and selector and positions the temperature control valve.	d. Duct temperature sensor
_____5.	Controls the mixture of hot and cold air entering the cockpit to maintain a selected temperature.	e. Cabin temperature sensor
_____6.	Provides automatic or manual control of the temperature control valve.	f. Temperature control switch
		g. Heat exchanger
		h. System shutoff valve

Answers to frame 33: 1. d 2. e 3. b 4. a 5. c 6. f

Frame 34

In the previous frames we followed airflow through a basic air conditioning system. We started with hot bleed air from the engines, cooled it by directing it through the heat exchanger and through the turbine fan assembly, and then directed it into the water separator to remove excess moisture. Then we discussed how the temperature is controlled by positioning the temperature control valve either automatically or manually. But, the pilot also needs a means of obtaining fresh air for ventilation should the air conditioning system fail. If the pilot needs fresh air, a ram air valve is provided. The ram air valve will allow outside air to enter the cockpit. This will not be conditioned air and may be cold or hot, depending on outside air temperature. To obtain ram air ventilation, the master switch, item 17 in the foldout, is turned from CABIN PRESS to RAM DUMP. This closes the cabin conditioning shutoff valve, item 2, and opens the cabin ram air valve, item 16. This method of bringing air into the cockpit is normally used only in an emergency.

NO RESPONSE REQUIRED.

1207

The ram air valve, illustrated at the right (item 16 on the foldout), consists of a 115-volt AC motor, a small scoop, and a hinged cap that serves as a check valve. When the valve is actuated open, the small scoop will open into the airstream allowing ram air to enter the cabin. When the scoop is opened, the pressure of the ram air will force the spring loaded hinged cap open. In the event the ram air valve is closed and is turned on again, the cap will close to prevent a loss of conditioned airflow. This is another scoop than the one mentioned in frame 12. That scoop takes in ram air for the air conditioning heat exchanger. After picking up heat, that ram air is dumped overboard. The ram air we are talking about here is for cabin fresh air or ventilation.

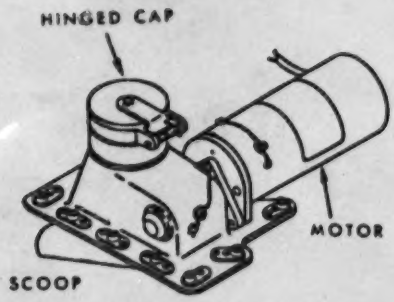


Figure 24.

Fill in the blanks to complete the following statements.

1. If the air conditioning system should fail, the pilot can receive outside air by opening the _____ _____ _____.

2. The ram air valve is actuated by an _____ _____.

3. The hinged cap serves as a _____ _____.

1208

WORKBOOK
3ABR42331-WB-129

Technical Training

Aircraft Environmental Systems Mechanic

TRAINER AIRCRAFT AIR CONDITIONING SYSTEM WIRING DIAGRAM

20 December 1978

CHANUTE TECHNICAL TRAINING CENTER (ATC)
3370 Technical Training Group
Chanute Air Force Base, Illinois

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1231

1209

Environmental Pneudraulics Branch
Chanute AFB, Illinois

TRAINER AIRCRAFT AIR CONDITIONING SYSTEM WIRING DIAGRAM

OBJECTIVE

Using electrical diagrams, identify 8 out of 10 circuit malfunctions when given the cause and circuit condition.

EQUIPMENT

	Basis of Issue
Colored pencils	1 set/student

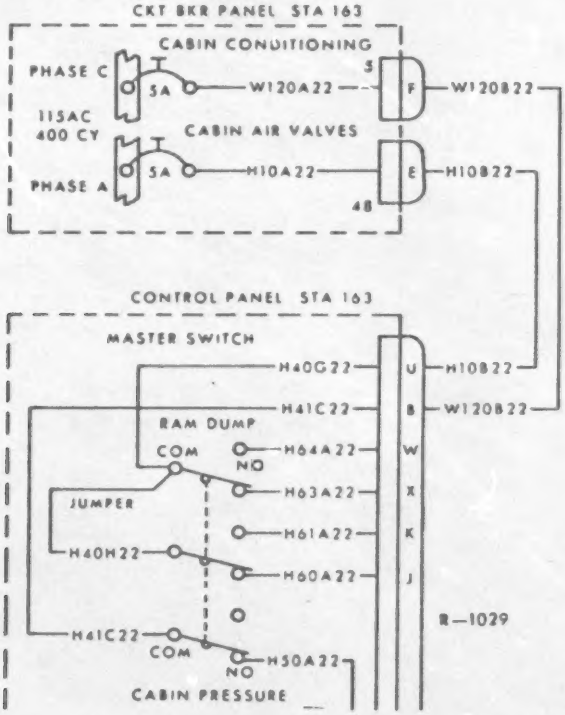
INSTRUCTIONS

Pay close attention to all directions that you are given in the text. When performing in the text, such as tracing or answering questions, if your response is incorrect, restudy the information. At the end of this workbook, you will have a progress check, which will be graded by your instructor. If you are ready to begin, and have no questions, proceed with the lesson.

Supersedes 3ABR42331-WB-118, 7 October 1977.
OPR: 3370 TCHTG
DISTRIBUTION: X
3370TCHTG/TTGU-P - 400; TTVSA - 1

Exercise 1

Using a red pencil, trace in the two power supply circuits, one from the cabin conditioning circuit breaker to the master switch and the other from the cabin air valves circuit breaker to the master switch. Do this in the figure below at this time. Do not trace through the master switch.

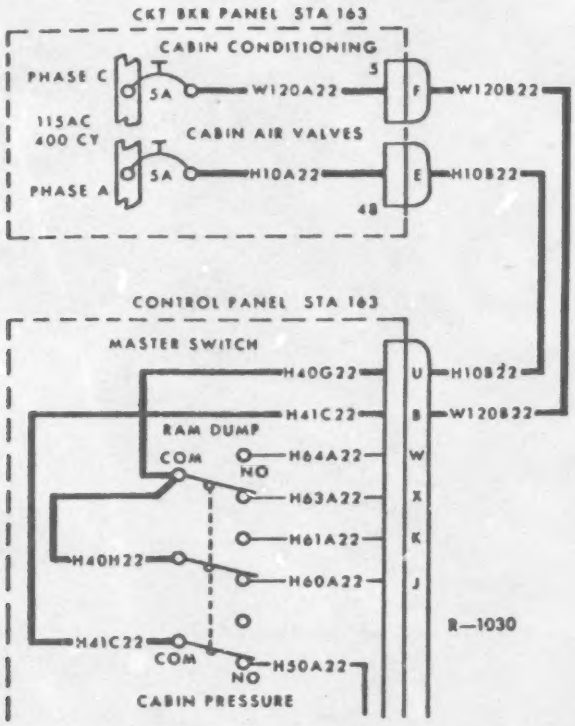


After tracing the above diagram, turn the page and compare the diagram that you have traced with the diagram on the following page.

1211

Confirmation for Exercise 1:

The bold lines in the diagram below indicate the circuit that you should have traced



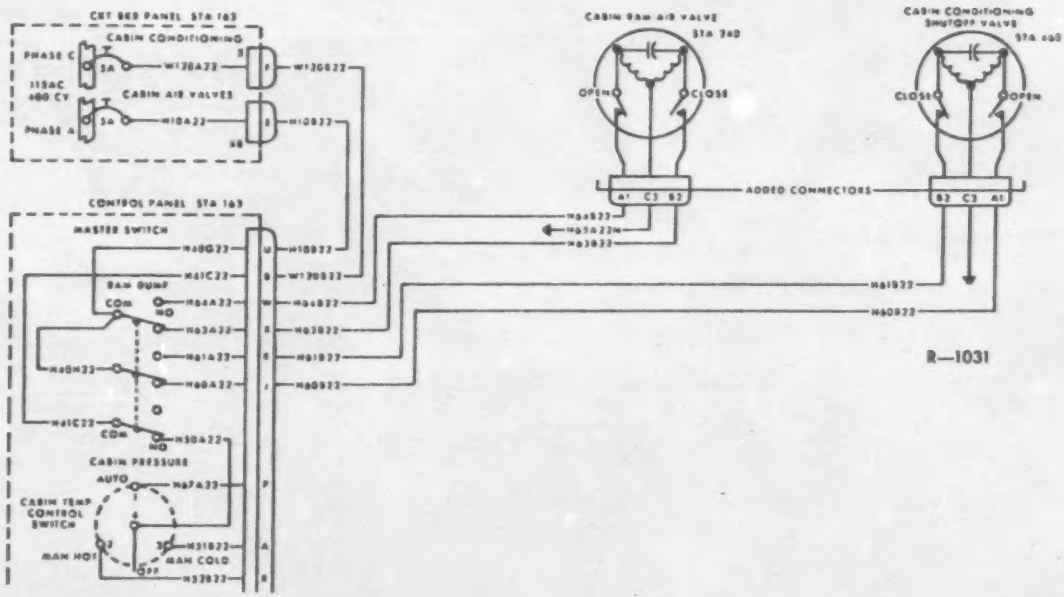
If your diagram was correct, continue the lesson. If not, see your instructor.

Exercise 2

CABIN AIR VALVES CIRCUITS

1. Using a purple pencil, in the figure below trace the cabin air valves circuits and temperature control switch circuit, with the master switch in the CABIN PRESSURE position only. After tracing these circuits, proceed to paragraph 2.

2. Using a brown pencil, in the figure below trace the cabin air valves circuits with the master switch in the RAM DUMP position.

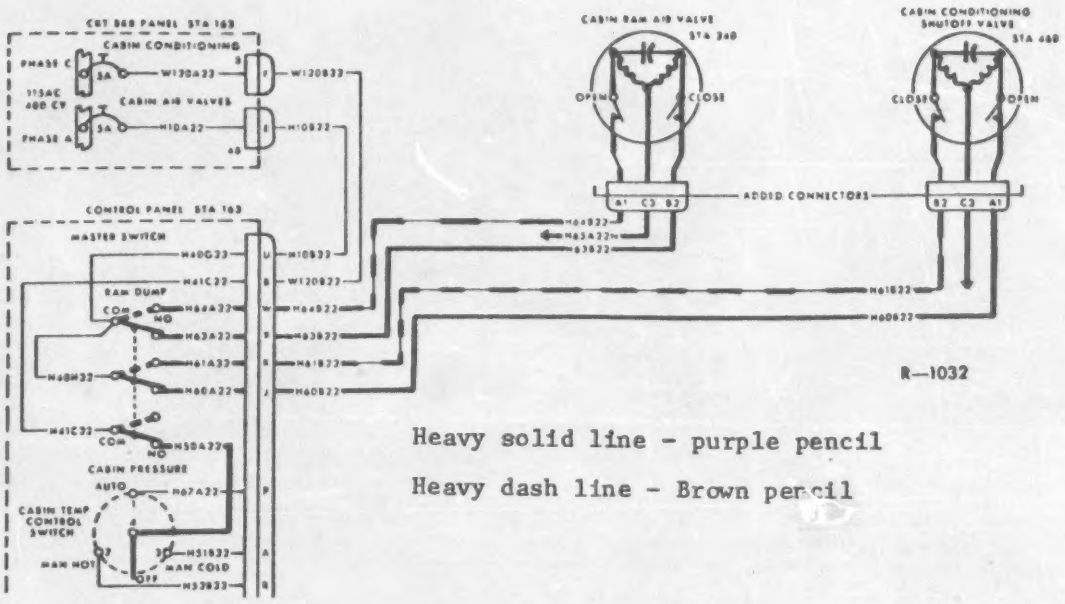


Turn the page and compare the diagram that you have traced with the diagram on the following page.

Note: In the AC motor for the two air valves you must trace through the microswitch. Now trace to both sides of the capacitor and through both motor windings and out the motor ground wire. In AC motors, current must flow through both windings if it is to open or close. The capacitor provides the needed phase relationship between the windings.

Confirmation for Exercise 2:

The bold lines in the diagram below indicate the circuits that you should have traced with the master switch in the CABIN PRESSURE position. The dashes indicate the circuits with the master switch in the RAM DUMP position. Note that the circuits are only traced from the master switch to the valves. Power was traced to the master switch in the previous diagram.



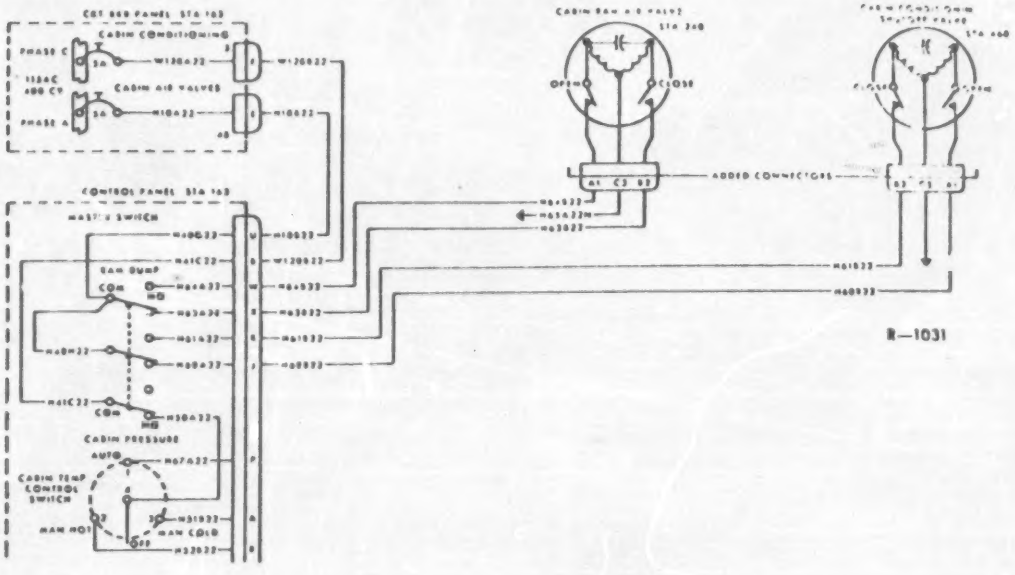
Heavy solid line - purple pencil

Heavy dash line - Brown pencil

If you have traced the diagram correctly, proceed to exercise 3; if incorrect, see your instructor.

Exercise 3

Using a purple pencil, draw the master switch in the cabin pressure position and the cabin temp control switch in the off position. Now draw in the complete circuit in the figure below to the air valves. You will start at the circuit breakers and complete the circuit to the air valve grounds and cabin temp control switch.



Circle the correct answer for each question below.

1. The master switch is in what position in the circuit traced above?

   a. Ram Dump.
   b. Cabin Pressure.

2. In the circuit you have traced above, the cabin ram air valve will

   a. open.
   b. close.

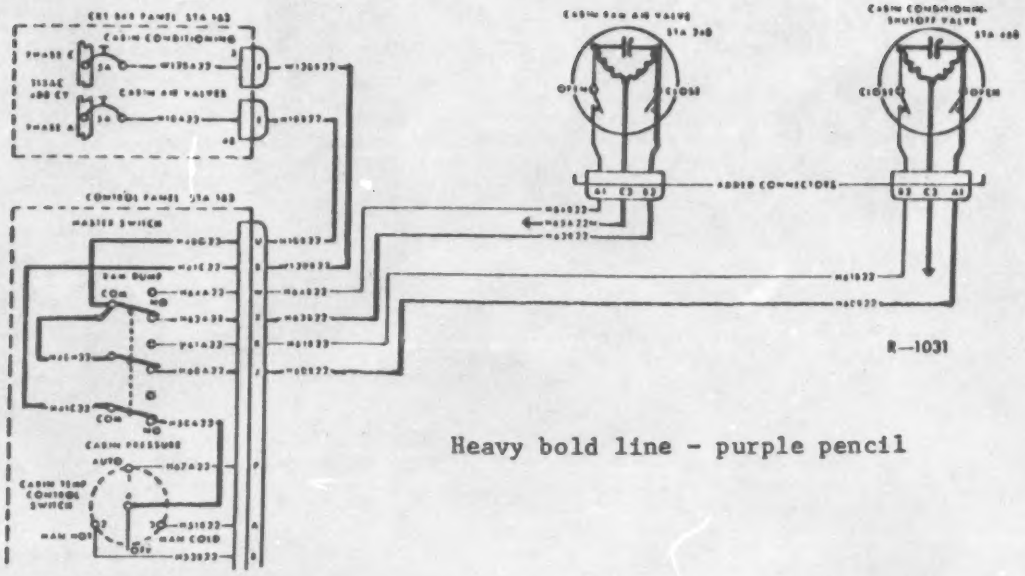
3. In the circuit you have traced above, the cabin conditioning shutoff valve will

   a. open.
   b. close.

Turn the page and compare the diagram that you have traced with the diagram on the following page. Also check your responses to the above questions on the following page.

1215

Confirmation for Exercise 3:



Heavy bold line - purple pencil

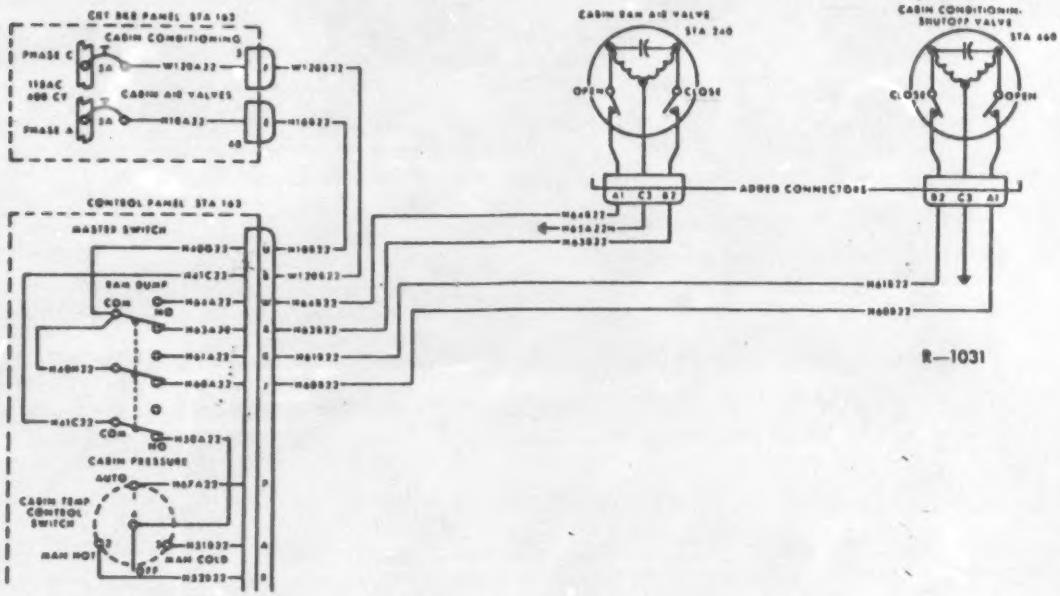
Correct answers to the questions:

1. b 2. b 3. a

If you have answered the questions correctly and traced the diagram correctly, proceed to exercise 4. If your answers are incorrect, see your instructor.

Exercise 4

Using a brown pencil, draw the master switch in the ram dump position. Now draw in the complete circuit in the figure below to the air valves. You will start at the circuit breakers and complete the circuit to the air valves grounds.



Circle the correct answer for each question below.

1. The master switch is in what position in the circuit traced above?

   a. Ram Dump.
   b. Cabin Pressure.

2. In the circuit you have traced above, the cabin ram air valve will

   a. open.
   b. close.

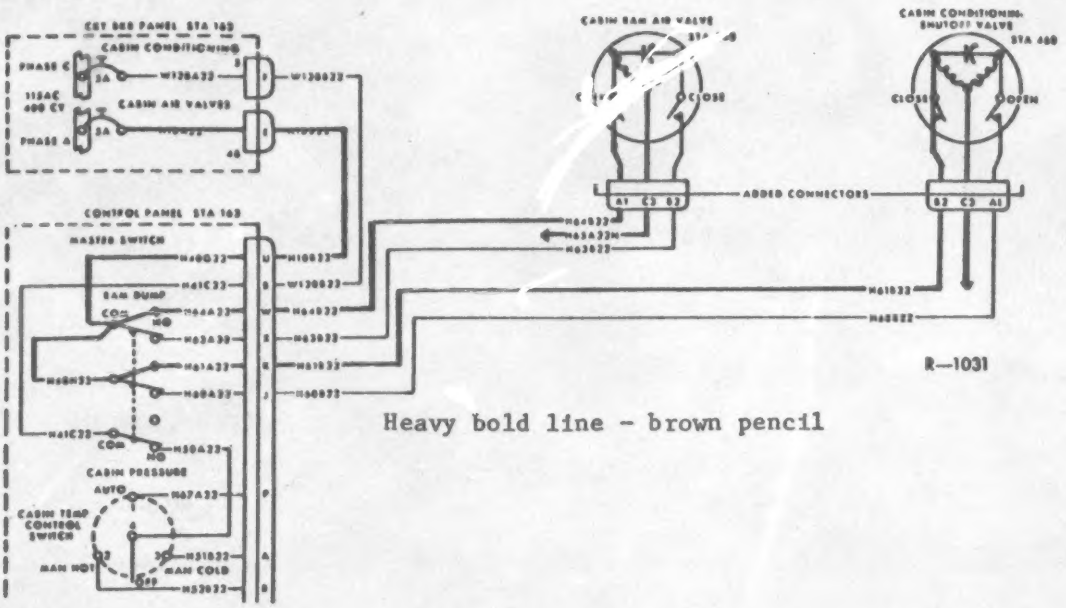
3. In the circuit you have traced above, the cabin conditioning shutoff valve will

   a. open.
   b. close.

Turn the page and compare the diagram that you have traced with the diagram on the following page. Also check your responses to the above questions on the following page.

1217

Confirmation for Exercise 4:



Heavy bold line - brown pencil

Correct answers to the questions:

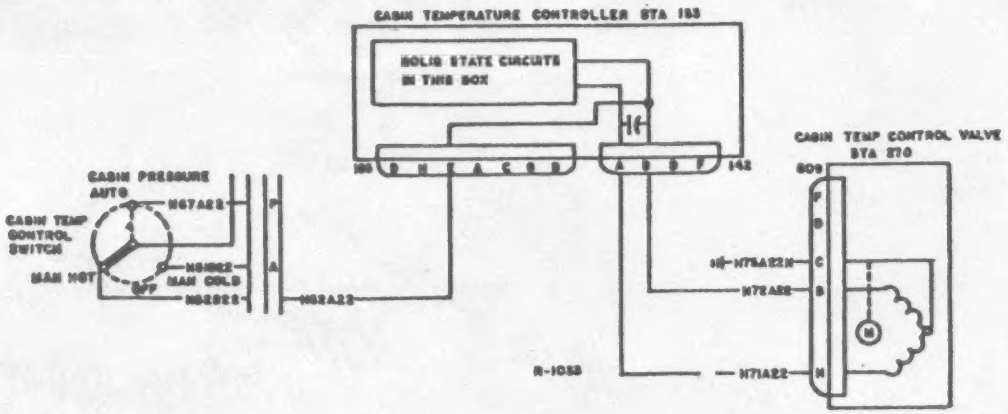
1. a 2. a 3. b

If you have answered the questions correctly and traced the diagram correctly, proceed to exercise 5. If your answers are incorrect, see your instructor.

Exercise 5

MANUAL HOT TEMPERATURE CONTROL CIRCUIT

Using a green pencil, trace the manual hot temperature control circuit starting at the temperature control switch to pin E of the controller, into the controller, across the capacitor, out both A and B pins of plug 142 to the temperature control valve. Then trace from B and H of plug 809 through both motor windings, across the common ground wire, and pin C of plug 809 to a ground connection.



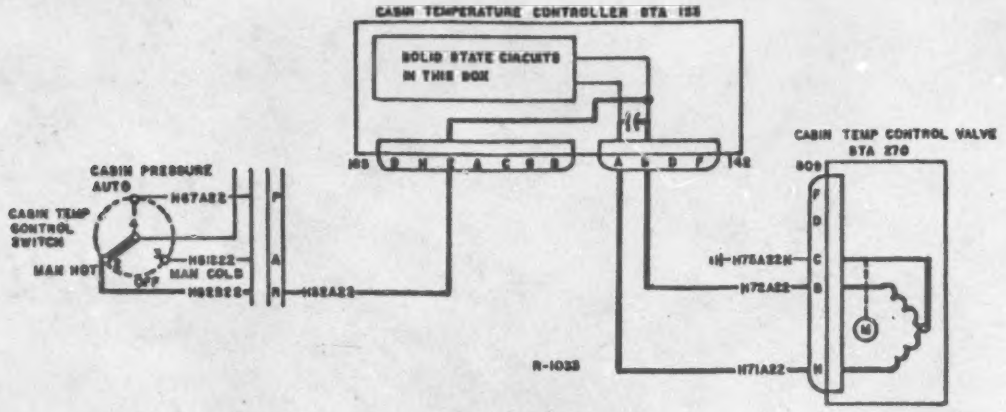
Note: The cabin temperature control valve uses AC power from only phase C. Because this valve uses single phase, it needs a capacitor across its windings like the cabin air valve motors. The capacitor used for the motor's two windings is located in the cabin temperature controller. Because of the capacitor's electrical location in the circuit, power will phase shift through the capacitor and down BOTH power leads to the motor to open or close the valve.

Turn the page and compare the diagram that you have traced with the diagram on the following page.

After you have completed tracing the manual hot circuit, proceed to exercise 6.

Confirmation for Exercise 5:

The bold lines in the diagram below indicate the circuit that you should have traced.

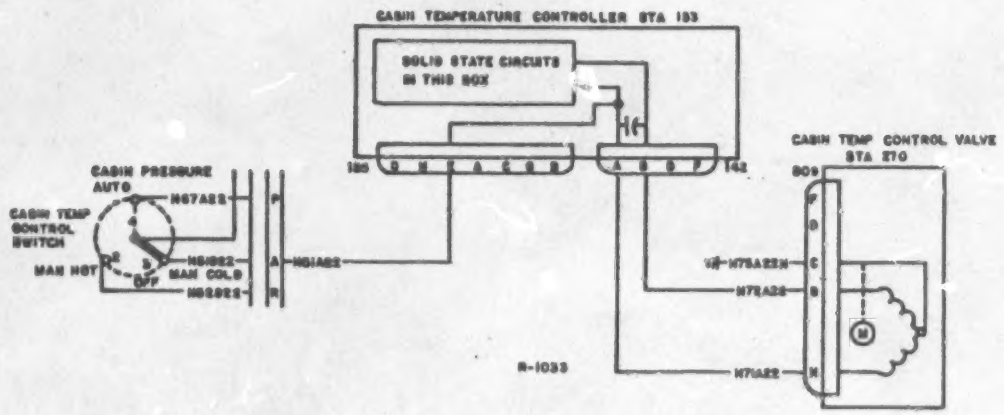


If your diagram was correct, continue the lesson. If your diagram is incorrect, see your instructor.

Exercise 6

MANUAL COLD TEMPERATURE CONTROL CIRCUIT

Using a black pencil, trace the manual cold temperature control circuit starting at the temperature control switch to pin H of the controller and from the controller out both A and B pins to the temperature control valve.



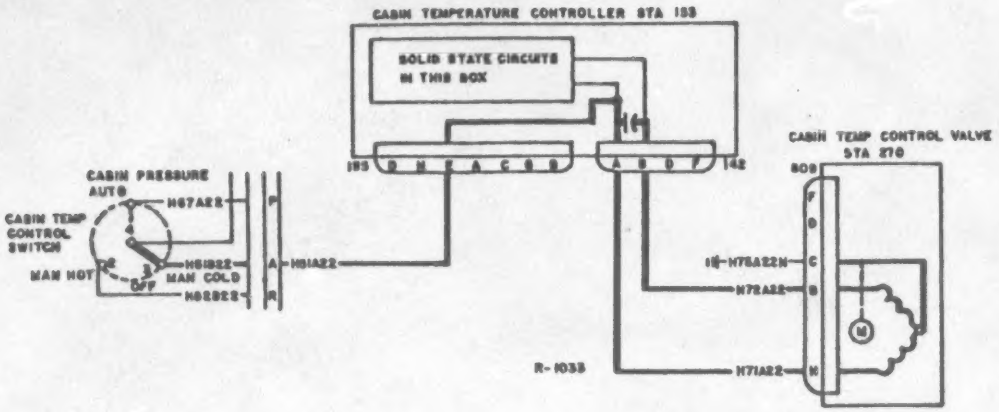
Note: Applying AC power to the appropriate side of the capacitor will control the direction of the motor rotation. This in turn will open or close the valve.

After you have completed tracing the manual cold circuits, proceed to exercise 7.

Turn the page and compare the diagram that you have traced with the diagram on the following page.

Confirmation for Exercise 6:

The bold lines in the diagram below indicate the circuit that you should have traced.

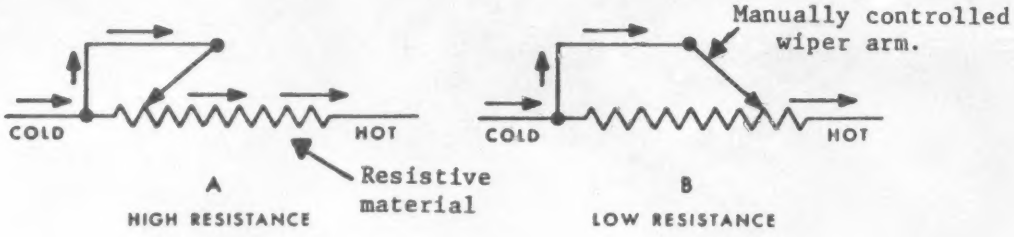


If your diagram was correct, continue the lesson. If your diagram is incorrect, see your instructor.

1222

TEMPERATURE SELECTOR SWITCH

The temperature selector switch is a manually controlled variable resistor or more commonly called a potentiometer. It is used to choose the temperature that is wanted in the cockpit only during automatic operation. It does this by either increasing or decreasing the resistance in one leg of the bridge circuit. In the sketch below, note how the resistance is increased in sketch A and decreased in sketch B.



The point at which the wiper arm touches the resistor is called the "control point." The control point is set by the pilot when he puts the temperature selector to the temperature he wants held. The reference to "control point" is important to remember for we will be referring to it again when we talk about the duct temperature sensor.

A high resistance in the temperature selector will cause the system to call for cold air. A low resistance in the selector will cause the system to call for hot air.

Fill in the blanks to complete the following statements.

1. A high resistance in the temperature selector calls for _____ air.

2. A low resistance in the temperature selector calls for _____ air.

3. The point where the wiper arm touches the resistor is called the _____ _____.

Turn the page and check your answers. If your answers are correct, proceed to exercise 8. If your answers are incorrect, see your instructor.

Answers to questions for Exercise 7: 1. cold 2. hot 3. control point

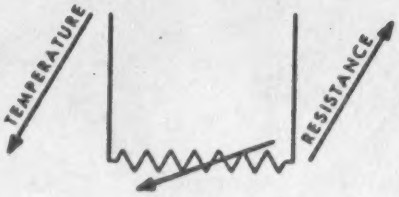
Exercise 8

SENSOR OPERATION

The sensors, since they are part of the bridge circuit, will have a small amount of current flow through both of them. Now that we know this, we will see how the ambient air temperature around each of the sensors, will cause the resistance of each of the sensors to change, and in turn, control which way the current will flow across the bridge. This is the action we want and also what will cause the system to run hot or cold, and keep the right temperature. Do not forget that both of the sensors have a negative coefficient of resistance. An increase in the air temperature will drop the sensors resistance. A drop in the air temperature, will raise the sensors resistance. The sketch, as shown below, may help you in not forgetting what you have so far learned. Sketch A shows that when the air temperature goes up, the resistance will go down. This will cause more current to flow through the sensor. Sketch B shows that when the temperature goes down, the resistance will go up, and this will cause less current to flow through the sensor.

A

TEMPERATURE INCREASE, RESISTANCE DECREASES. SYSTEM CALLS FOR COLD.



B

TEMPERATURE DECREASE, RESISTANCE INCREASES. SYSTEM CALLS FOR HOT.

Fill in the blanks to complete the following statements.

1. If the ambient air temperature around the sensor goes up, the resistance goes _____.

2. An increase of current flow through the sensor will call for _____ conditioned air from the air conditioning system.

3. A decrease in current flow through the sensor will call for _____ conditioned air from the air conditioning system.

4. If the ambient air temperature around the sensor goes down, the resistance will go _____.

Turn the page and check your answers. If your answers are correct, proceed to exercise 9. If your answers are incorrect, see your instructor.

Answer to Exercise 8: 1. down 2. cold 3. hot 4. up

Exercise 9

What you have learned so far is the normal operation of the temperature sensors and the temperature selector in the automatic mode of operation. What will happen when the selector and/or sensors fail? The failing of these should be a short or an open. For you to find out what happens to the circuit operation with bad sensors you must keep the following in mind. The sensor, when it is open, has an infinite resistance. The sensor with a short has zero, or no resistance in it.

Do not forget that the high temperature outside the sensor will have to change the resistance in the sensor. This high temperature will take it to a normal low resistance and this will cause the system to give cold air. If the sensor had a short, it would go to a unwanted low resistance and call for unwanted cold air. With a low temperature outside the sensor, the resistance in the sensor will go to one of high resistance. This change to a high resistance will call for hot air. Also, an open, which is high resistance, will tell the system to call for unwanted hot air.

If you have a short or an open in the cabin sensor, the air in the cabin will get either full auto cold or full auto hot from the system.

If you have an open or short in the duct sensor, the cabin air will receive either full auto hot or full auto cold, but there can be some control by the temperature selector. This characteristic of the sensors is due to their position on the bridge circuit.

Answer the following questions T for true and F for false.

1. An open in the cabin sensor would give a signal of low resistance calling for cold air. _____

2. A short in the duct sensor will give a full cold signal before any adjustment is made. _____

3. Cabin temperature sensor is fully controllable, even if it is shorted or open. _____

4. A shorted cabin sensor gives a low resistance signal calling for cold air. _____

Turn the page and check your answers. If your answers are correct, proceed to exercise 10. If your answers are incorrect, see your instructor.

Answers to Exercise 9: 1. F 2. T 3. F 4. T

Exercise 10

TRAINER AIR CONDITIONING SUMMARY OF SENSORS AND TEMPERATURE SELECTOR

UNIT	CHARACTERISTICS	TYPE OF SIGNAL	RESULTING AIR
Cabin Sensor	Negative coefficient In automatic when the unit malfunctions and is not controllable.	High resistance signal or an open	Hot air to cabin
		Low resistance signal or a short	Cold air to cabin
Duct Sensor	Negative coefficient In automatic when the unit malfunctions some control is possible with temperature selector.	High resistance signal or an open	Hot air to cabin
		Low resistance signal or a short	Cold air to cabin
Temperature Selector (Potentiometer)	In automatic operation when this unit malfunctions the circuit is not controllable.	High resistance signal or an open	Cold air to cabin
		Low resistance signal or a short	Hot air to cabin

Answer the following statements T for true and F for false.

_____1. Full auto hot air to the cabin indicates a shorted temperature selector.

_____2. High resistance signal in the duct sensor sends a signal which will call for hot.

_____3. Full auto cold in the cabin is due to low resistance in the cabin sensor.

_____4. Full auto cold in the cabin air conditioning is due to a open in the cabin temperature selector.

_____5. The cabin and duct and temperature selector work exactly alike.

_____6. If the temperature on the outside is higher, then the resistance of the sensor would be low.

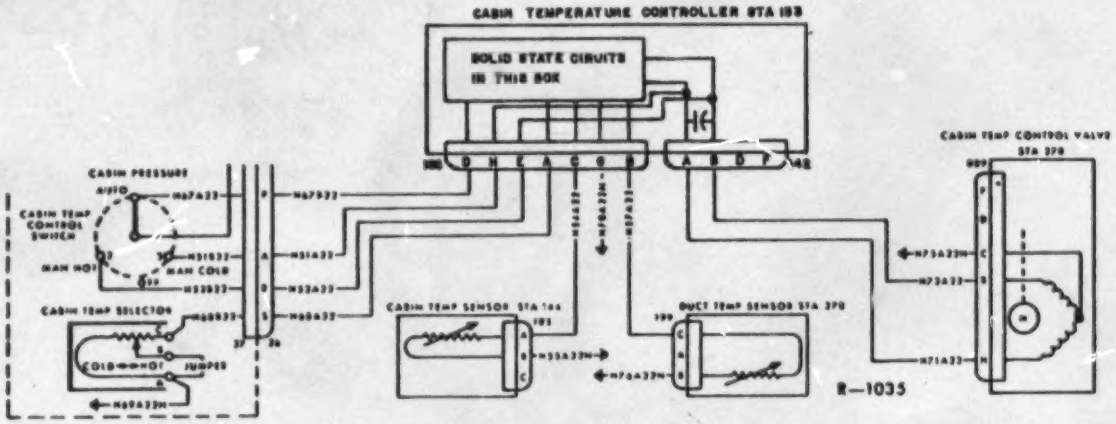
Turn the page and check your answers. If your answers are correct, proceed to exercise 11. If your answers are incorrect, see your instructor.

Answers to Exercise 10: 1. T 2. T 3. T 4. T 5. F 6. T

Exercise 11

AUTOMATIC TEMPERATURE CONTROL CIRCUIT

You will use an orange pencil to trace in the automatic temperature control circuit. You must start to trace from the temperature control switch. Now you will trace from the control switch to the solid state box in the temperature controller. Next you should trace from the solid state box, down the two leads, to the temperature control valve. Do not forget to trace both leads. Now trace in the temperature selector, and both of the sensor circuits. Do not forget to start at the ground for each item and trace it to the solid state box. We will not learn the solid state circuit for it is too complex for you at this time. You do not need to know the way it works to be able to troubleshoot the rest of the circuit.



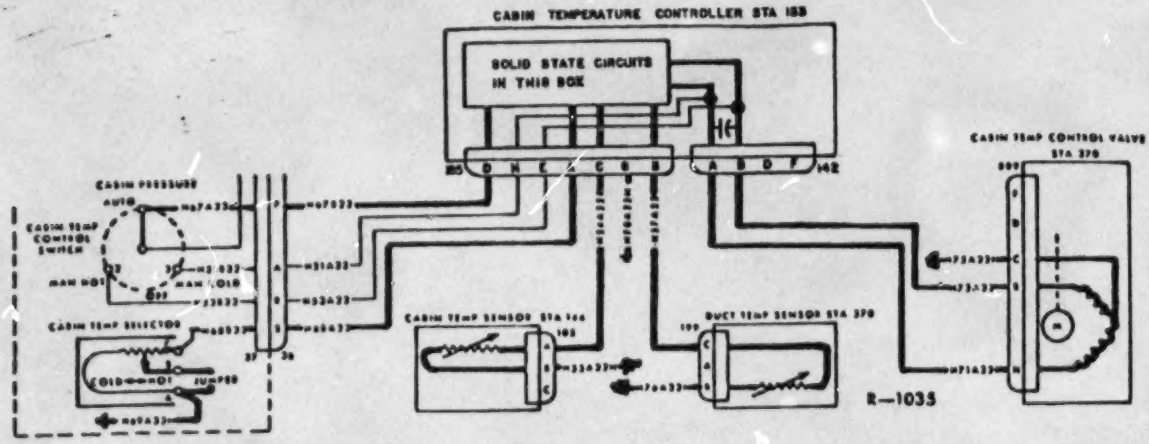
Note: See notes in exercises 5 and 6.

After tracing in the diagram as directed, turn the page and compare the diagram that you have traced with the diagram on the following page.

1227

Confirmation for Exercise 11:

The bold lines in the diagram below indicate the circuits that you should have traced.



If your diagram was correct, proceed on to exercise 12. If your diagram is incorrect, see your instructor.

Exercise 12

Check your understanding of the system operation by filling in the blanks to complete the following statements.

1. The cabin temperature control valve is actuated by a _____ phase AC motor.

2. When the temperature control switch is placed in the MAN HOT position, the temperature control valve will _____ (open/close).

3. The two modes of temperature control system are _____ and _____.

4. To operate the temperature control valve, the circuit must be complete to _____ windings.

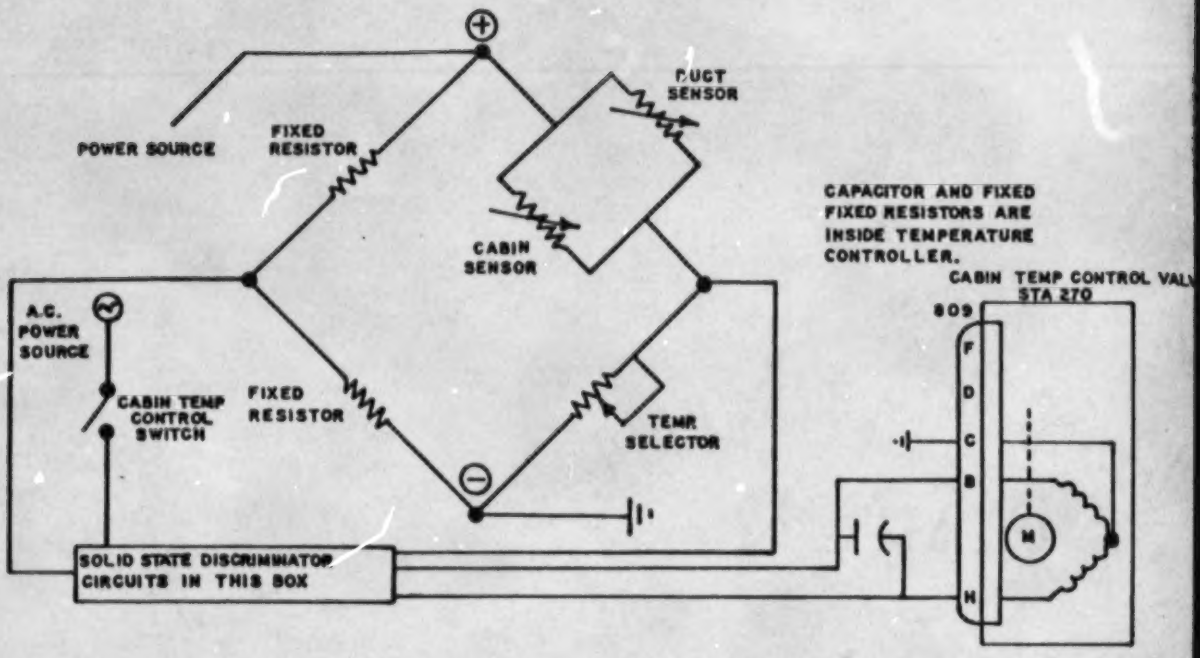
5. To operate the temperature control system, the master switch must be in the _____ _____ position.

6. The temperature control system receives power from the _____ _____ circuit breaker.

7. The temperature sensors both have a _____ coefficient of resistance.

8. When the air conditioning system shutoff valve is open, the ram air valve is _____.

Turn to page 23 and check your answers. If you have answered the questions correctly, proceed to exercise 13. If you have answered the questions incorrectly, review the past 12 exercises.



Complete the following statements by filling in the blanks below.

1. Only hot air entering the cockpit is an indication of a/an _____ cabin sensor.

2. A shorted cabin sensor will cause the air entering the cockpit to be _____.

3. An open or shorted duct sensor will change the _____ _____ of the temperature selector.

4. Both sensors have a _____ coefficient of resistance.

5. When the duct sensor malfunctions, the temperature can still be partially controlled by the _____ _____.

6. When the _____ sensor malfunctions, the temperature of the air entering the cockpit will be either full hot or full cold and cannot be controlled automatically.

Turn the page and check your answers. If you have answered the questions correctly, proceed to exercise 14. If you have answered the questions incorrectly, review the past 13 exercises.

Anwwers to Exercise 12: 1. single 2. open 3. manual automatic 1230
4. both 5. cabin pressure
6. cabin conditioning 7. negative
8. closed

1253

Answers to Exercise 13: 1. open 2. cold 3. control point 4. negative 5. temperature selector 6. cabin

Exercise 14

This is the progress check. The next 10 problems will not be done any place but in the classroom and under the supervision of the instructor. You will not do these problems in the barracks or at home. You must identify a minimum of 8 out of the 10 circuit malfunctions correctly. Your instructor must check your work after the ten (10) problems. If your instructor says your work is satisfactory, the instructor will initial your work allowing you to progress. If the instructor says your work is unsatisfactory, it will not be initialed and you will follow the instructions of the instructor. To complete the progress check, you must identify the following malfunctions with the numbered troubles from foldout 1. You will do this by writing in the numbers from foldout 1 in blanks a - j below. Have your instructor check and initial your work before further progression.

a._____ Only the cabin ram air valve will not open.

b._____ Automatic and manual temperature control is inoperative.

c._____ Automatic temperature control is inoperative. Manual operation is normal.

d._____ Ram air valve remains open while the air conditioning system operates in cabin pressure position.

e._____ Only manual HOT control is inoperative.

f._____ In automatic, only cold air will enter the cockpit.

g._____ Cabin air valves will not open or close.

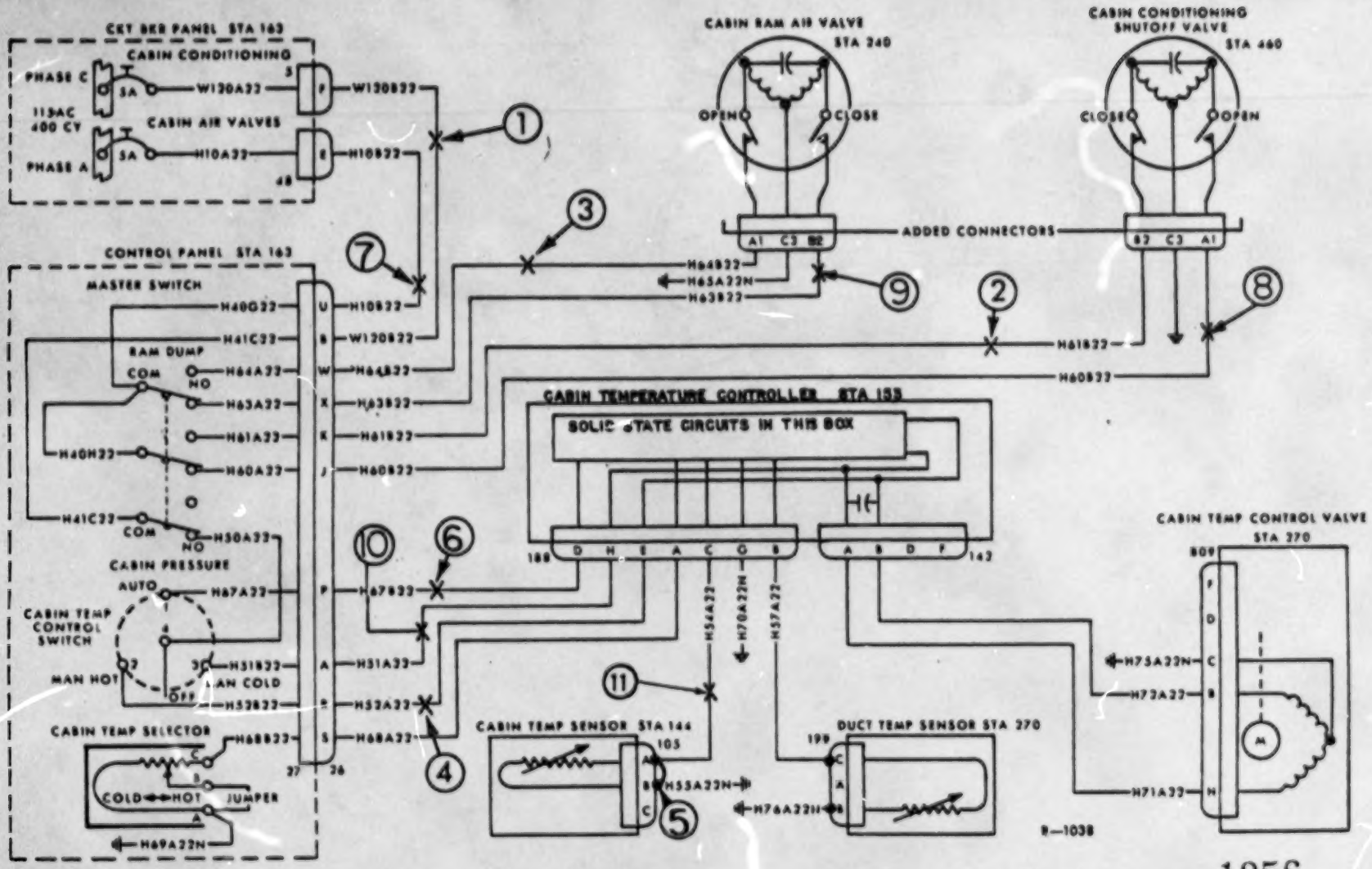
h._____ The air conditioning system will not shut down. The cabin ram air valve operates normally.

i._____ In automatic, only HOT air will enter the cockpit.

j._____ Cabin air conditioning system will not turn on. Cabin ram air valve is operating normally.

INSTRUCTOR'S INITIALS _____

This completes your study of the trainer wiring schematic. Report to your instructor and turn in your workbook and ask the instructor to check your answers to the above problems.


CKT BKR PANEL STA 163
CABIN CONDITIONING
PHASE C
5A
W120A22
115AC 400 CY
CABIN AIR VALVES
PHASE A
5A
H10A22
W120B22
H10B22
CONTROL PANEL STA 163
MASTER SWITCH
H40G22
H41C22
RAM DUMP
COM
NO
H64A22
H63A22
H61A22
H40H22
H60A22
H41C22
COM
NO
H50A22
CABIN PRESSURE
AUTO
H67A22
CABIN TEMP CONTROL SWITCH
MAN HOT
MAN COLD
OFF
H31B22
H52B22
CABIN TEMP SELECTOR
H68B22
COLD
HOT
JUMPER
H69A22N
H10B22
W120B22
H64B22
H63B22
H61B22
H60B22
H67B22
H31A22
H52A22
H68A22
CABIN RAM AIR VALVE STA 240
OPEN
CLOSE
A1 C3 B2
CABIN CONDITIONING SHUTOFF VALVE STA 460
CLOSE
OPEN
B2 C3 A1
ADDED CONNECTORS
H64B22
H65A22N
H63B22
H61B22
H60B22
CABIN TEMPERATURE CONTROLLER STA 153
SOLID STATE CIRCUITS IN THIS BOX
188
D H E A C G B
A B D F
142
H54A22
H70A22N
H57A22
CABIN TEMP SENSOR STA 144
105
H55A22N
H76A22N
DUCT TEMP SENSOR STA 270
199
CABIN TEMP CONTROL VALVE STA 270
809
H75A22N
H72A22
H71A22
M
B-1038
1256
1255
Foldout 1. Basic Air Conditioning System.

1233

WORKBOOK

3ABR42331-WB-129A

Technical Training

Aircraft Environmental Systems Mechanic

TRAINER AIRCRAFT AIR CONDITIONING SYSTEM TROUBLESHOOTING

16 October 1978

CHANUTE TECHNICAL TRAINING CENTER (ATC)
3370 Technical Training Group
Chanute Air Force Base, Illinois

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1257

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1234

Environmental Pneudraulic Branch
Chanute AFB, Illinois

3ABR42331-WB-129A

TRAINER AIRCRAFT AIR CONDITIONING SYSTEM TROUBLESHOOTING

OBJECTIVES

Using a trainer, electrical diagram, and multimeter, troubleshoot system and record a minimum of four causes for five malfunctions.

EQUIPMENT

	Basis of Issue
Multimeter	1/student
Grease Pencil	1/student
Cloth Eraser	1/student
Trainer 3301, Air Conditioning System	1/student

PROCEDURE

1. REMOVE ALL JEWELRY. Report to the lab instructor and inform him or her of the lesson that you are working on. The instructor will provide you with the materials needed for this lesson.

2. Look at figure 1 on page 3. This figure shows the trainer that you will be working with and will help you to locate the various components. You must be able to locate and identify each component to correctly perform the operational check and troubleshooting. After you are familiar with the trainer you may continue with this lesson.

3. Also, when you leave your trainer for scheduled or unscheduled breaks insure the following steps have been done before you go.

a. Place the control switch to the off position and pull the two circuit breakers.

b. Secure your multimeter during this period.

(1) Insure the controls are set on the proper settings for storage.

(2) Leave the test leads attached to the meter.

(3) Wrap the leads around the meter.

(4) Place the meter on the locker shelf.

c. When you return from the break take the same meter and go back to work.

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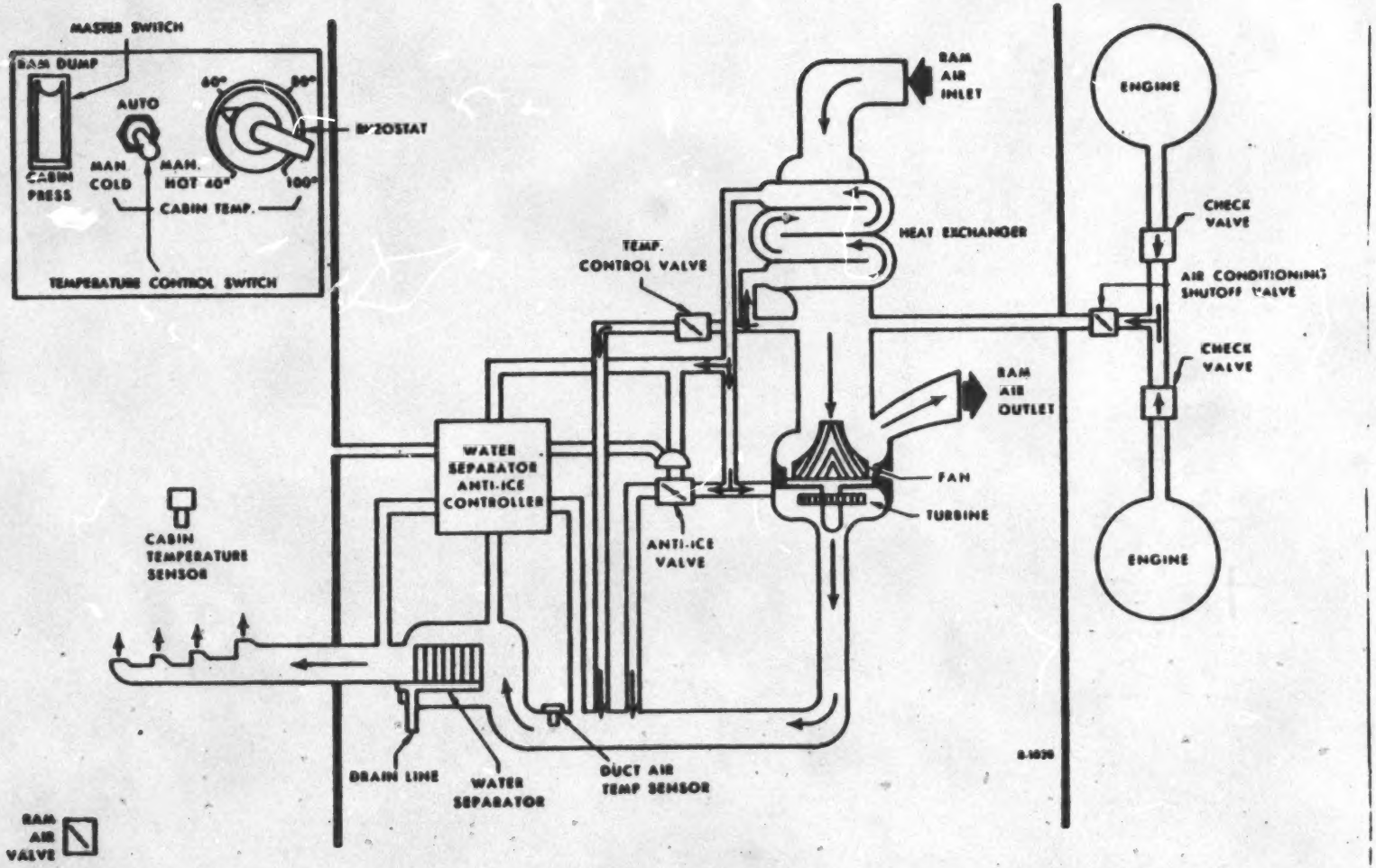

Figure 1. Air Conditioning System Trainer Layout.

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PROJECT 1

Troubleshooting is the word used to describe a mechanic's locating mechanical and electrical failures. This worksheet is designed to acquaint you with a basic approach to troubleshooting. It is highly unlikely that any two individuals will troubleshoot in exactly the same manner. You, as an Environmental Systems Specialist, will have to develop your own technique as you gain experience on the systems. But, regardless of the technique used, the problem must first be solved in the troubleshooter's mind; that is, all of the possibilities are thought out until the most likely one is determined.

When troubleshooting electrical failures, the multimeter is an essential tool. However, the multimeter does not do the actual troubleshooting. You must first analyze the system and determine the possible causes. Then use the meter to verify the actual cause.

Circle the number of each true statement below.

1. Troubleshooting is used to locate mechanical and electrical failures.

2. The multimeter does all of the troubleshooting for you.

3. Analyze the system for possible causes, then verify them with the multimeter.

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Answers to Project 1: 1, 3

PROJECT 2

During this lesson you will be using the multimeter to test for voltage and resistance in the circuits and components. In previous lessons you were taught how to use the multimeter. The quiz below will help you recall how to use the multimeter.

Before completing the quiz, open the meter, and prepare it for use.

Using the meter as an aid, fill in the blanks to complete each of the following statements.

1. The Ohms scale is colored _____.

2. The negative probe is colored _____.

3. When checking for resistance, the trainer power must be turned _____.

4. The multimeter is used for testing _____ and resistance.

5. The aC volts scale is colored _____.

6. When checking for resistance the function selector must be set on _____ and the range selector to the desired ohms range.

7. To test a 115 volt AC circuit, the function selector must be set to _____ and the range selector to _____.

8. If an accurate reading is to be obtained with the ohmmeter, it must be _____.

Answers to Project 2: 1. green 2. black 3. off 4. voltage 5. black 6. ohms 7. AC, 250 volts scale 8. zeroed

PROJECT 3

Before we continue with the use of the multimeter, we need to learn how the trainer air conditioning system is operating. Let's do this by making an operational check.

OPERATIONAL CHECK PROCEDURES

1. Make sure all trouble switches at the left end of the trainer are in the OUT position, and the trainer power switch located in the upper left hand corner is placed to the OFF position.

2. Insure the trainer power cable is connected to an AC outlet, and make sure all circuit breakers on the trainer are pushed in.

3. Place the trainer power switch to the ON position.

4. Place the following switches to the positions listed below.

   Master switch to CABIN PRESS position.

   Temperature control switch to OFF (center) position.

   Temperature selector switch (potentiometer) to the 60° position.

Note: As you perform each of the following steps, place an X in the blank provided that correctly indicates the valve position.

5. Place the master switch to the RAM DUMP position.

   a. Cabin ram air valve opened _____ closed _____.

   b. Cabin conditioning shutoff valve opened _____ closed _____.

6. Place the master switch to the CABIN PRESS position.

   a. Cabin ram air valve opened _____ closed _____.

   b. Cabin conditioning shutoff valve opened _____ closed _____.

7. With the master switch still in the CABIN PRESS position, hold the cabin temperature control switch to the MANUAL HOT position.

   The temperature control valve is now moving open _____

close _____.

8. Hold the cabin temperature control switch to the MANUAL COLD position.

The temperature control valve is now moving open _____ close _____.

9. Place the cabin temperature control switch to the AUTO position.

10. Rotate the temperature selector (potentiometer) to the HOT (100°) position.

The cabin temperature control valve is now moving open _____ close _____.

11. Rotate the temperature selector to the COLD (40°) position.

The cabin temperature control valve is now moving open _____ close _____.

12. Place the master switch to the RAM DUMP position.

The ram air valve opened _____ closed _____, and the cabin conditioning shutoff valve opened _____ closed _____.

13. With the master switch still in the RAM DUMP position, place the temperature control switch to each of the following positions and observe the temperature control valve.

MANUAL HOT position, MANUAL COLD position, and AUTO.

Did the cabin temperature control valve operate with the switch in any of the positions? Yes _____ No _____

This completes the operational check procedure, now compare your answers to those below. This way you will know that the trainer is operating normally.

Answers to Project 3:

5. a. opened
   b. closed
6. a. closed
   b. opened
7. open
8. close
9. open
10. close
12. opened, closed
13. no

If all of your answers agree with the ones given above, you are ready to begin troubleshooting. If you do not agree, perform the operational check again or ask your instructor for assistance.

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PROJECT 4

In the previous lesson you learned about the sensors and the potentiometer and what happens if they malfunction. This knowledge is essential for you to do effective troubleshooting. Let's see what you remember.

Complete the following statements by filling in the blanks.

1. Only hot air is entering the cockpit in automatic. This would be an indication of an _____ cabin sensor.

2. An open duct sensor will change the control point of the _____.

3. A shorted cabin sensor will cause the air entering the cockpit to be _____.

4. Both sensors have a _____ coefficient of resistance.

5. A shorted _____ _____ will change the control point of the potentiometer.

6. An open in the potentiometer circuit would cause _____ air to enter the cabin.

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Answers to Project 4: 1. open 2. potentiometer 3. cold 4. negative 5. duct sensor 6. cold

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PROJECT 5

You should recall from the previous lesson that the sensors and the potentiometer are variable resistors. To check then, we use the ohms portion of the meter.

Procedure for checking resistance of the sensors with a multimeter.

1. Place the trainer power switch to the OFF position.
2. Set the mater Function Selector to Ohms.
3. Set the range selector switch.

Note: The easiest part of the scale to read is near the center of the scale. Use the range setting that will place the needle near the center when reading the resistance according to the sensor resistance values.

4. Isolate the bridge circuit. You do this by disconnecting the cannon plug at the section marked 188 on the cabin temperature controller. This process is to disconnect all the components of the bridge for individual ohm check. You did this same type of exercise when you pulled out the junction pins on the bridge circuit trainer in the lab.

6. Locate the cabin sensor on the wiring diagram. Notice that the circuit coming from ground goes through pin B of the cabin sensor, out pin A, and then to pin C of the controller.

7. Now locate the cabin sensor on the trainer. Place one multimeter lead in plug 105, pin B, and the other lead in pin A. This circuit is illustrated below.

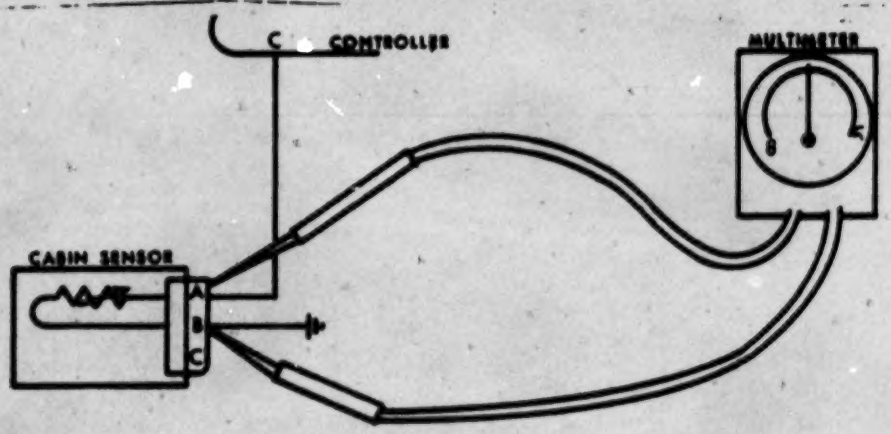

Figure 2. Checking Sensor Resistance.

8. Read the resistance and record it. _____

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9. Now locate the duct sensor and measure its resistance.

Duct sensor resistance is _____ ohms.

10. Both of these resistance values should be between 16,000 and 47,000 ohms. If the values you have recorded are not within this range, ask the instructor for assistance.

Now that you know the resistance of the sensors you can use this information during troubleshooting. When you check them again during troubleshooting they should have close to the same resistance values.

To check out the cabin temperature selector you must isolate the bridge circuit by disconnecting plug 188 and then ohm out the potentiometer. You must connect the meter leads at ground and either Pin S on plug 26 or Pin A on plug 188. The resistance should vary on the meter when the temperature selector is rotated. If it does not show any resistance you have a short in the potentiometer.

When troubleshooting, if you get a zero (0) reading on the meter, it means the sensor is shorted. If you get an infinity (∞) reading on the meter, it means the sensor is open.

Complete the following statements by filling in the blanks.

1. Trainer power should be turned _____ when using the ohmmeter.

2. If the meter indicates zero, it means the sensor is _____.

3. If the meter indicates infinity, it means the sensor is _____.

4. When checking for ohms, the function selector must be set to _____.

5. To check sensors and potentiometers, you should use the _____ portion of the multimeter.

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Answers to Project 5: 1. off 2. shorted 3. open 4. ohms 5. ohms

PROJECT 6

Now let's find out how to check a wire for resistance. Normally a wire has extremely small resistance, and the ohmmeter should read zero.

Locate wire number H54A22 on the wiring diagram. This wire connects the cabin sensor to the controller. An open in this wire would be like having an open in the cabin sensor.

Check the resistance of wire number H54A22 by performing the following steps.

Note: Anytime you find a need to troubleshoot in the bridge circuit be sure to isolate the circuit with plug 188 and then ohm out the circuit.

1. Place the trainer power switch to the OFF position.
2. Set the function selector to OHMS.
3. Set the range selector to Ω x 100 and zero the meter.
4. Put one lead in pin "C" connection at the controller and the other lead in pin "A" connection at the cabin sensor. This test circuit is illustrated below.

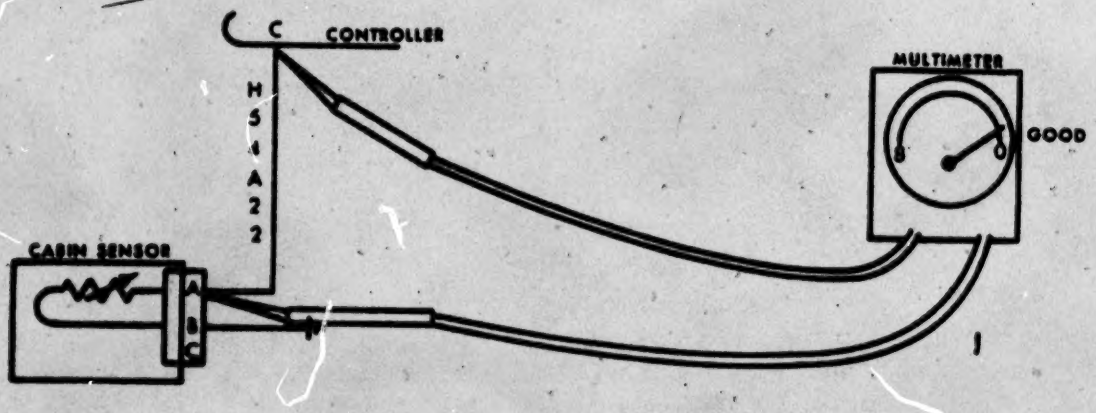

Figure 3. Checking Wire Resistance.

If the meter reads zero (0) the wire is good. If the meter reads other than zero, it either has an open or a high resistance.

Complete the following statements by filling in the blanks.

1. A good wire has _____ resistance.
2. When using an ohmmeter, the power switch should be _____ _____.
3. When measuring the resistance of a wire, if the meter reads other than zero, the wire is _____ or has a high _____.

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Answers to Project 6: 1. small (zero) 2. off 3. open, resistance

PROJECT 7

Most of your troubleshooting will be done using the voltmeter portion of the multimeter. The only time you should use the ohmmeter is for checking the sensors or potentiometer circuits (bridge circuit).

To illustrate this point, let's make a comparison. Locate the master switch on the trainer. This switch controls the air conditioning shutoff valve. Locate the shutoff valve. On the trainer it would be possible to check the wire from the master switch to the shutoff valve with an ohmmeter. But let's compare this to the same circuit on the T-38 aircraft by noting the illustration below. On the actual aircraft this valve is several feet from the switch. Imagine the difficulties one man would have in checking this same circuit from the cockpit to the shutoff valve with an ohmmeter.

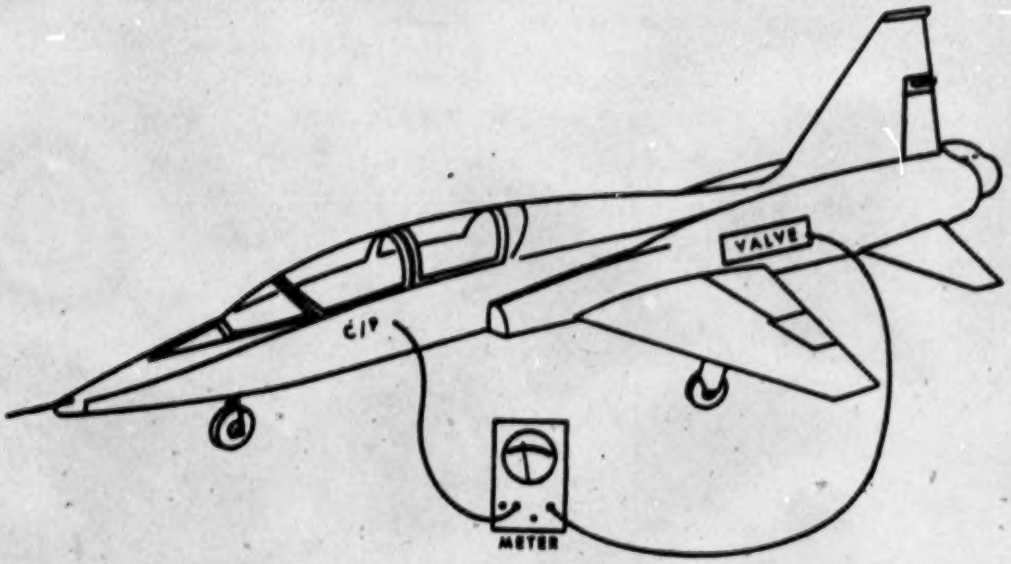

Figure 4. Voltmeter or Ohmmeter?

To prepare yourself for troubleshooting circuits on the aircraft, USE THE VOLTMETER FOR TROUBLESHOOTING THE TRAINER CIRCUITS. Use the ohmmeter for checking the sensor or rheostat circuits only.

Complete the following statements by filling in the blanks.

1. To check the sensor and potentiometer circuits, you should use _____.

2. For most of your troubleshooting, you should use the _____.

3. An ohmmeter is always used to check _____ and _____.

4. The most practical meter used when troubleshooting is the _____.

Answers to Project 7: 1. ohmmeter 2. voltmeter
3. sensors and potentiometer 4. voltmeter

PROJECT 8

Before using the multimeter to check voltage, let's see if you know how the system operates normally. Run through an operational check again. Start with the switches in the normal positions. Go back to project 3 for the procedure if necessary.

When you are sure you know how the system operates normally, perform the following steps.

1. Place trouble switch number 1 to the IN position.

2. Place the trainer power switch to the ON position.

3. Perform an operational check to determine which component does not operate properly.

Note: You should have found that the air conditioning shutoff valve did not open.

4. Using the grease pencil and the wiring diagram on the trainer, trace the circuit from the cabin air valves circuit breaker to the open side of the shutoff valve.

Note: The diagram below illustrates how the circuit should look when traced on the diagram.

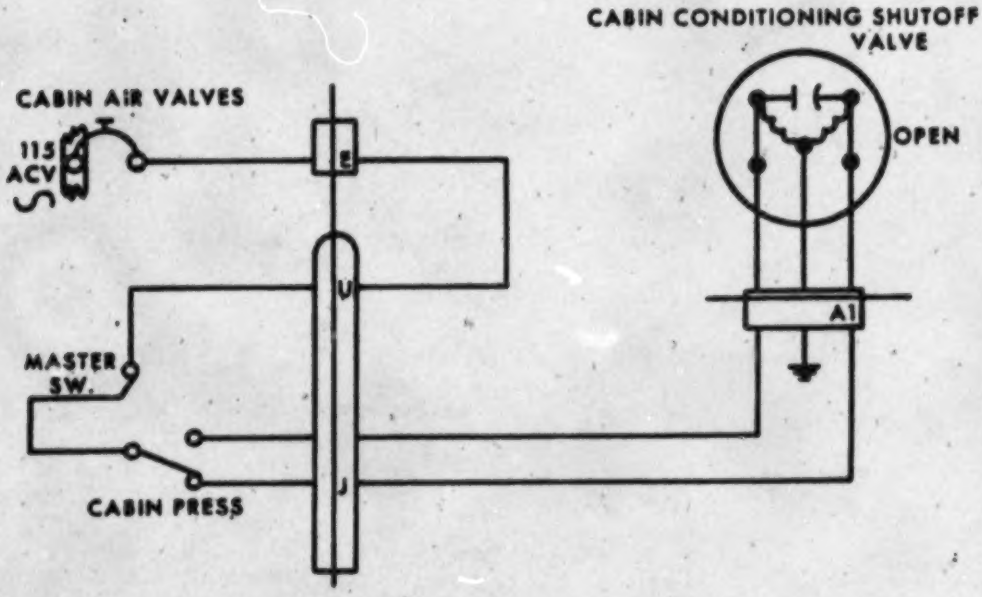

Figure 5. Circuit Tracing.

5. Analyze the circuit to determine why the valve didn't open. Ask yourself, where would an open be that might prevent the valve from opening.

PROJECT 9

Now let's use the voltmeter to see if you were right.

1. Leave the trainer power switch ON. Check the wiring diagram and determine the type of voltage you will be measuring. The voltage is indicated at the circuit breaker on the wiring diagram.

2. Set up the meter for checking this voltage.

3. When you are checking for voltage, the black lead (negative) is always connected to ground. Locate, on the trainer, the small metal strip marked AIRCRAFT GROUND. Place the black lead in this ground, and leave it there while checking for voltage. This metal strip represents the frame of the aircraft. When checking for voltage on the aircraft, the frame (metal) of the aircraft is ground.

4. Place the red lead (positive) in pin A1 of the shutoff valve.

Is there power at pin A1? Yes _____ No _____

You should have answered NO. There is no power at pin A1, but there should be.

5. Now trace the circuit back and find the next check point. This is pin "J" on control panel 26. Place the red lead in pin "J." Is there power at this point? Yes _____ No _____

You should have answered YES, there should be power at this point.

Complete the following statements by filling in the blanks.

1. There is an open in wire number _____.

2. The voltage for the circuit checked is _____.

3. You had the function selector on _____.

4. You had the range selector on _____.

5. The color of the meter scale you used is _____.

6. On the aircraft, any part of the frame can be used as an _____.

7. When measuring voltage, the lead that goes to ground is the _____ lead.

Answers to Project 9: 1. H60B22 2. 110 - 120 volts AC 3. AC volts
4. 250 5. black 6. ground 7. black (negative)

PROJECT 10

While performing the steps in projects 8 and 9, you have actually completed troubleshooting one malfunction. Let's review the steps you followed after placing the trouble in the system.

Step 1: Perform an operational check.

Step 2: Determine the malfunctioning component and how it malfunctioned (the valve wouldn't open).

Step 3: Trace the circuit on the wiring diagram.

Step 4: Analyze the circuit for possible causes (which wire could be open or which unit could be defective).

Step 5: Use the multimeter to verify the possible causes and determine the actual cause.

Performing the operational check is a step-by-step procedure used to cause all components to operate. This procedure is given to you in project 3. When working on an actual aircraft, this procedure is given in the technical order.

To determine the malfunctioning component you must know how each component is supposed to operate normally. Then you observe each component's operation to see if it does operate normally.

Tracing the circuit on the diagram helps you select the circuit or circuits that are involved in operating the malfunctioning component. This is the first step in isolating the problem.

Analyzing the circuit for the possible causes requires you to consider all of the available information (symptoms). Let's review the analysis for trouble switch number 1. Follow on the diagram as we analyze this problem. From the operational check we found that the air conditioning system shutoff valve would not open, but the ram air valve does open and close. With this information we know the circuit bringing power to the master switch is good. Since the problem is "the valve won't open," we can assume the close circuit to be good. This leaves our possibilities to be wire number H60B22, wire number H60A22, the ground wire, or a defective valve motor.

After determining the possible causes through analysis, the meter is used to determine where power is and find the actual cause.

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PROJECT 11

Troubleshooting

Apply the five steps of troubleshooting to determine the cause for the trouble in each of the problems. You are to complete the remaining 3 practice problems, before you do your progress check. Each problem is placed into the trainer by one of the trouble switches. The trouble switches you are to use are not in numerical sequence - check the chart on the following page for the trouble switches to use.

Note: When troubleshooting the manual temperature control system, be sure you hold the temperature control switch in either the manual Hot or manual Cold position.

Note: Anytime you find a need to troubleshoot in the bridge circuit be sure to isolate the circuit with plug 188 and then ohm out the circuit.

Troubleshoot the system and determine the cause for the trouble in each of the problems. Place only one trouble switch to the IN position for each problem. Start with problem number written in by the instructor. After completing each problem, be sure to place the switch for that problem to the OUT position.

Record your findings for each problem on the chart. We have completed problem number 1 and the information has been filled out.

When you have completed the 3 practice problems, report to the instructor and the instructor will check your answers. If you are correct, you are ready for the progress check.

Note: When you find a HIGH RESISTANCE in a malfunctioning circuit, be sure that you have the circuit isolated that is showing the HIGH RESISTANCE. This may be done by disconnecting the unit electrical plug.

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On the chart below list the following information.

In block A, name the unit that is malfunctioning.

In block B, state how the unit is malfunctioning - example: will not open, will not close, will not operate in automatic.

In block C, state the actual cause, giving the wire number or unit and whether it is an open or a short or high resistance.

After you go over the first problem which was done for you, do the next three practice problems and have the instructor check your work when you are done.

Note: Use only the trouble switch that is given by instructor for each problem.

PROBLEM NUMBER 1	TROUBLE SWITCH 1
A Air Conditioning System Shutoff Valve	
B Will Not Open	
C Wire #H60B22 Open	
PROBLEM NUMBER 2	TROUBLE SWITCH
A	
B	
C	
PROBLEM NUMBER 3	TROUBLE SWITCH
A	
B	
C	
PROBLEM NUMBER 4	TROUBLE SWITCH
A	
B	
C	

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Student complete the following (print).

STUDENT NAME _____
LAST FIRST

DATE THE PROGRESS CHECK STARTED _____

PROGRESS CHECK

You must locate 4 causes for 5 malfunctions (5 problems).

Each problem has a total of 5 pts

A = 1 pt.

B = 1 pt.

C = 3 pt.

Over the whole progress check you cannot miss more than a total of 5 pts.

PROBLEM NUMBER 1	TROUBLESWITCH NO.
A	
B	
C	
PROBLEM NUMBER 2	TROUBLE SWITCH NO.
A	
B	
C	
PROBLEM NUMBER 3	TROUBLE SWITCH NO.
A	
B	
C	
PROBLEM NUMBER 4	TROUBLE SWITCH NO.
A	
B	
C	

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PROGRESS CHECK (Cont'd)

PROBLEM NUMBER 5	TROUBLE SWITCH NO.
A	
B	
C	

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If you have satisfactorily completed the progress check, store your multimeter and trainer in the following way.

1. Place all trouble switches toggles to the out position. These are located on the left side of the trainer.

2. Push in circuit breakers and turn on trainer power.

3. Place the master switch in cabin pressure position with red cover also down.

4. Place the cabin temperature control switch to the center off position.

5. Place the trainer power switch in off position.

6. Pull out all the circuit breakers (2) two each.

7. Push in the work table on the trainer.

8. Insure all your training literature, pencils etc are taken with you when you leave the lab.

9. Insure your trainer and the area around it is clean before you leave the lab.

10. Properly store and sign in your multimeter before you leave the lab.

11. Check with the lab instructor before you leave the lab.

Note: Did you leave your multimeter turned on? If you have, go back and correct it.

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